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REPORT OF THE ARCTIC CHARR AQUACULTURE WORKSHOP, MARCH 12, 1991 ST. JOHN'S, NEWFOUNDLAND

Editor: R. W. Penney

Science Branch
Department of Fisheries and Oceans
St. John's, Newfoundland
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Industry reports contain the results of research and development useful to industry for either immediate or future application. They are directed primarily toward individuals in the primary and secondary sectors of the fishing and marine industries. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

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TABLE OF CONTENTS

EDITOR'S REMARKS v

ABSTRACT vii

WORKSHOP PRESENTATIONS

Brown, J. A., J-P. Thonney, D. Holwell, and W. R. Wilson. Proliferative kidney disease (PKD) and Arctic charr 1

Brown, G. E., J. A. Brown and R. K. Srivastava. The behavioural regulation of growth in Arctic charr (Salvelinus alpinus) 5

Srivastava, R. K., J. A. Brown and F. Shahidi. Seasonal changes in egg quality of Arctic charr, (Salvelinus alpinus) L. 15

Sutterlin, A. M. Some experience with Arctic charr compared with Atlantic salmon and rainbow trout at the Bay D'Espoir Salmon Hatchery, Newfoundland 23

Shahidi, F., J. Synowiecki and R. W. Penney. Uptake of pigments in the flesh of Arctic charr derived from pigments in the diet 25

Penney, R. W. First year hatchery growth of an Arctic charr population, 1989-90 at NAFC 27

Dempson, J. B. Wild Arctic charr populations in Newfoundland and Labrador 35

Tabachek, J. L. Arctic charr aquaculture programs at the Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba 51

Tabachek, J. L. Comparison of the performance of rainbow trout (Oncorhynchus mykiss) and Arctic charr (Salvelinus alpinus) 57

de March, B. G. E. Genetic studies with Arctic charr at the Rockwood Aquaculture Research Centre, Winnipeg, Manitoba 67

INDUSTRY SESSION

Freeman, R. New Tech Char Farms Ltd. 71

Rex, F. Arctic charr aquaculture projects in the Bonavista Peninsula area 73

Turner, T. Valley Char Inc. 75

Robbins, N. Aquametrica Ltd. 77

WORKSHOP WRAP-UP 79

ACKNOWLEDGEMENTS 83

APPENDIX 1 85

APPENDIX 2 91

APPENDIX 3 101

APPENDIX 4 107

EDITOR'S REMARKS

In recent years, the level of aquaculture-related activity in Newfoundland has grown considerably. Spurred on by developments elsewhere in Canada and in other countries, both finfish and shellfish aquaculture ventures are being actively pursued by private industry or community-based development associations. Interest in Arctic charr as a candidate aquaculture species has arisen largely for the same reasons as elsewhere in Canada, namely, its greater ability to thrive in lower water temperatures than either rainbow trout or Atlantic salmon, its ability to thrive at high culture densities, and its current high market price and low market availability. Although new to Newfoundland in an aquaculture sense, Arctic charr are not new to the Newfoundland fishery, in that there has been a long standing commercial fishery for wild charr in northern Labrador.

Newfoundland faces a number of constraints to the development of salmonid aquaculture, as it is currently practised throughout Canada. Coastal, marine water temperatures throughout the province reach limits lethal to salmonids in winter. So, although the province is blessed with a long, deeply-indented coastline with many sheltered bays and inlets, traditional sea cage culture of salmonids is not feasible in most areas. The freshwater environment has its challenges, too. The range of seasonal freshwater temperatures in Newfoundland is similar to most parts of Canada. However, Spring arrives relatively late and winter sets in early so mean annual water temperatures in most river systems are lower than many parts of Canada. Thus, commercial producers of rainbow trout in flow-through, surface water systems are at a relative disadvantage, growth-wise, compared to facilities in other parts of Canada. In addition to environmental challenges, being the most eastern province (and an island) on the North American continent places aquaculture producers in this province at a considerable marketing disadvantage. Moving product to central Canadian and American population centres is expensive, compared to more centrally located producers in Ontario, Quebec, etc.

Nevertheless, Arctic charr culture has some exciting possibilities. At the time of this workshop, four aquaculture facilities in the province have recently started growing Arctic charr: Bay D'Espoir Salmon Hatchery at St. Alban's; Valley Char Inc. at Deer Lake; New Tech Char Farms Ltd at Port Rexton; and the Great Northern Peninsula Development Association Hatchery at Daniel's Harbour.

In February, I was contacted by Ms. Jo-Anne Tabachek of DFO's Freshwater Institute in Winnipeg concerning an upcoming visit to Newfoundland to discuss issues related to Arctic charr culture with growers and researchers in this province. The visit was sponsored by the Atlantic Fisheries Adjustment Program. This seemed the perfect catalyst to convene a workshop bringing together

researchers from the Freshwater Center, researchers in Newfoundland, and representatives of industry and community associations. Most researchers and industry people realize that charr culture is in its infancy. Many opportunities exist for improvements in culture technology, husbandry, genetics, broodstock development, etc. before charr culture will reach its full commercial potential.

In Newfoundland, we are just beginning to develop a salmonid aquaculture industry. So, not only are private entrepreneurs experimenting with a new species, but they are also facing the challenges of trying to construct new facilities in a new and unfamiliar industry. This does, however, offer us some advantages. The opportunity exists to build facilities specifically for Arctic charr to take advantage of its differences compared to other salmonid species. The next few years will be exciting ones in charr aquaculture. With some strong commitments from industry, government, research organizations, and a fair share of luck, Newfoundland can be a strong participant in this development.

The contents of this report represent the proceedings of the workshop held on March 12 at the Freshwater Resource Center in Pippy Park, St. John's. A great deal of timely and beneficial information is presented. Hopefully, this is just the first in what will prove to be a continuing series of information exchanges between researchers and industry.

Randy Penney
Editor

ABSTRACT

Penney, R. W. (ed.). 1991. Report of the Arctic charr aquaculture workshop, March 12, 1991, St. John's, Newfoundland. Can. Ind. Rep. Fish. Aquat. Sci. No. 212. viii + 109p.

Considerable interest has grown within governments and industry in Newfoundland concerning the feasibility of developing an Arctic charr aquaculture industry in the province. On March 12, 1991, researchers from various levels of government, university, or private industry in Newfoundland, and researchers from the Freshwater Institute in Winnipeg met in St. John's to discuss Arctic charr research and technology transfer issues with representatives of the aquaculture industry. The workshop report contains the text of 10 presentations (or their extended abstracts) by researchers, as well as abstracts of presentations by four representatives of the aquaculture industry. A synopsis of the more important points or conclusions reached during the workshop, as well as a considerable body of information of practical interest to commercial Arctic charr aquaculturists is also included. Many aspects of Arctic charr culture are covered including: fish husbandry, nutrition, feeding, temperature effects, broodstock management, genetics, growth, behaviour, disease problems, flesh pigmentation, etc. It was concluded that Arctic charr culture remains a strong commercial aquaculture prospect in Canada but that a significant R&D requirement still exists to overcome continuing difficulties with stock improvement, egg to fry survival, size variations during growth, broodstock development, and other problems.

RÉSUMÉ

Penney, R. W. (ed.) 1991. Rapport de l'atelier sur l'aquaculture de l'omble arctique, 12 mars 1991, St. John's, Terre-Neuve. Can. Ind. Rep. Fish. Aquat. Sci. No. 212. viii + 109 p.

À Terre-Neuve, les gouvernments et l'industrie se sont montrés fortement intéressés à la faisabilitié de créer une industrie de l'aquaculture de l'omblie arctique dans la province. Le 12 mars 1991, des chercheurs de gouvernment, de l'université et de l'industrie privée de Terre-Neuve ont recontré à St. John's des chercheurs de l'Institut des eaux douces de Winnipeg pour aborder des questions de recherche et de transferts de technologie sur l'omble arctique avec des délégués de l'industrie de l'aquaculture. Le rapport de cet atelier contient le texte de dix exposés de chercheurs (ou leurs résumés détaillés), ainsi que les résumés des exposés de quatre représentants de l'industrie de l'aquaculture. Un compte-rendu des données essentielles et des conclusions de l'atelier sont également inclus dans ce rapport, de même qu'un important bagage d'informations intérressant les aquaculturistes. De nombreaux aspects de l'élevage de l'omblie arctique y sont touchés, notamment: la pisciculture, la nutrition, l'alimentation, les effets de la température, la gestion des stocks reproducteurs, le génétique, la croissance, le comportement, les maladies, le pigmentation de la chair, etc. La conclusion permet de croire qu'il reste un fort potentiel pour l'aquaculture commerciale de l'omblie arctique au Canada, mais surmonter des problèmes persistants, entre autres sur les plans de l'amélioration des stocks, de la survie du stade de l'oeuf à celui de l'alevin, des variations de taille durant la croissance et du développement de stocks reproducteurs.

PROLIFERATIVE KIDNEY DISEASE (PKD) AND ARCTIC CHARR

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In 1986, Arctic charr (Salvelinus alpinus) parr being reared at the Marine Sciences Research Laboratory in St. John's, Nfld., Canada, suffered mortality due to proliferative kidney disease (PKD). Other salmonids reared under the same conditions did not suffer any mortality. This led us to hypothesize that the charr had not been exposed to the PKX organism and therefore had not developed a resistance to the disease. We set up an experiment to compare the susceptibility of Arctic charr and landlocked Atlantic salmon (Salmo salar ouananiche) to the PKX organism.

Approximately 8 weeks after water temperatures had reached 12°C, the mortality of Arctic charr began to increase and remained high during the period of high water temperature (>12°C). No increase in mortality of ouananiche was observed.

Histopathological diagnoses determined that PKD was the cause of the high mortality of charr. No PKX was found in the ouananiche samples or among charr taken when water temperatures were below 12°C. Our results show that charr, in contrast to ouananiche, have not developed a resistance to PKD. The pattern of the disease was very similar to that reported for rainbow trout.

TABLE 1

Results of histopathological analysis for proliferative kidney disease in Arctic charr, landlocked salmon and threespine sticklebacks. See text for details.

Month	Temp.	Species	Comment
May	<12°C	Landlocked salmon	No PKD
		Arctic charr	No PKD
		Threespine stickleback	No PKD*
July	12°-14.9°C	Landlocked salmon	No PKD
		Arctic charr	No PKD
August	15°-18°C	Landlocked salmon	No PKD
		Arctic charr	PKD**
September	>18°C	Landlocked salmon	No PKD
		Arctic charr	PKD**
		Threespine stickleback	No PKD

* Sphaerospora-like cells noted in kidney

** Diagnosed as cause of mortality

Figure 1. Percent mortality (number dead/number at start of exp.) of Arctic charr (•) and landlocked Atlantic salmon (o). Ambient temperature divided into categories.

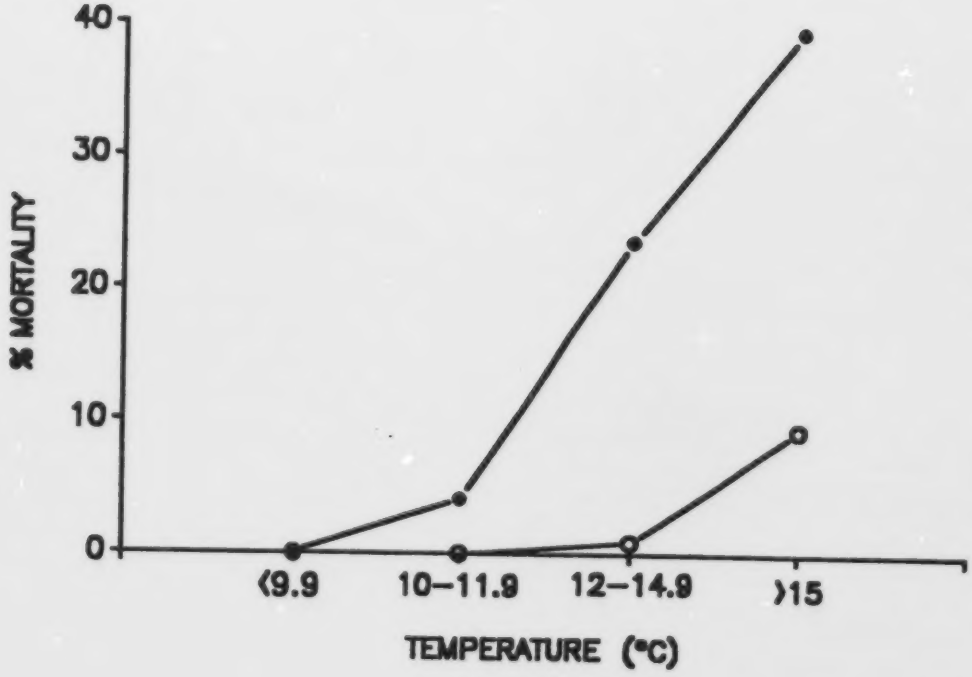
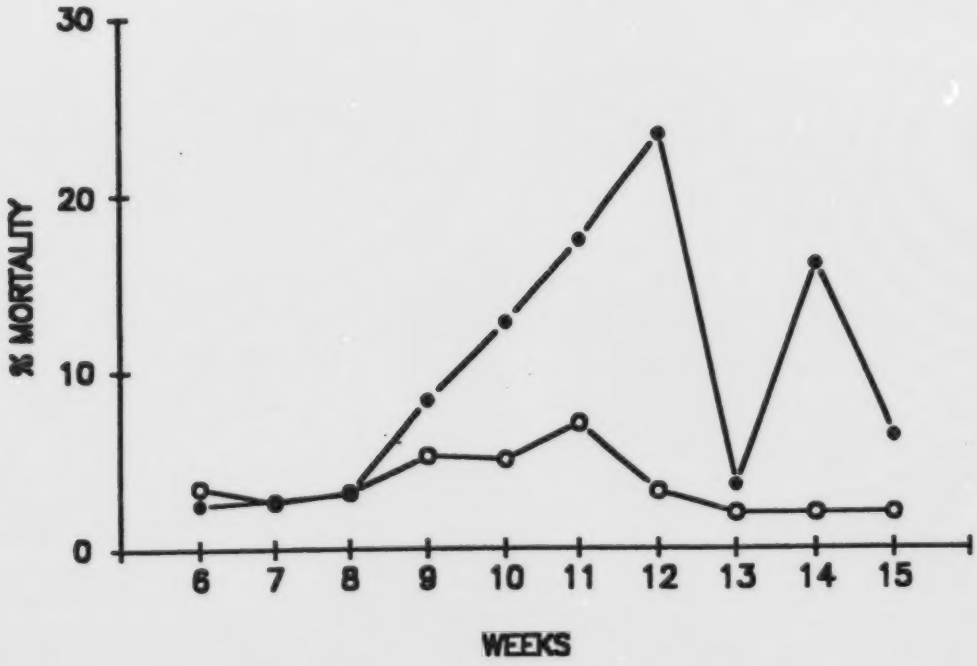


Figure 2. Percent mortality (number dead/number at start of exp.) of Arctic charr (•) and landlocked Atlantic salmon (o) during weeks after temperature had reached 12°C.



THE BEHAVIOURAL REGULATION OF GROWTH IN ARCTIC CHARR (*SALVELINUS ALPINUS*)

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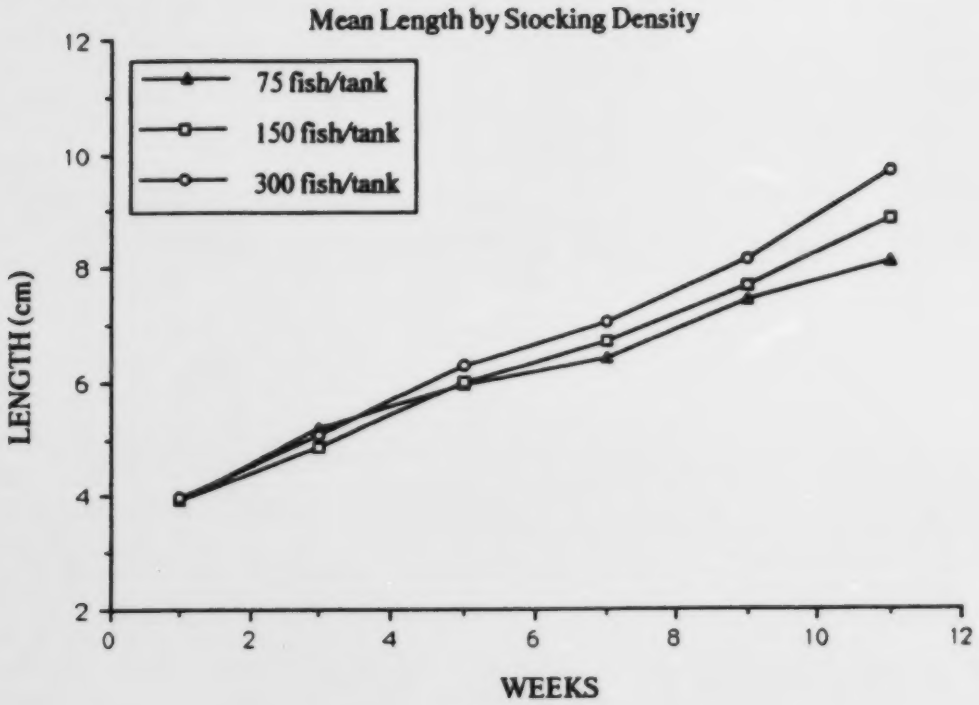
It is commonly observed that the growth rate of Arctic charr is higher and less variable when they are held at high stocking densities. The reason for this is assumed to be due to a reduction in aggression at the high densities. An experiment was designed to examine the relationship among density, aggression, and growth in juvenile Arctic charr. Young-of-the-year charr were reared at densities of 75, 150, and 300 fish per 65 litre tank. Fish were videotaped once a week, and growth measurements were taken once every two weeks. Videotaped observations were later analyzed for: 1)form and frequency of agonistic interactions, and 2) per cent time spent swimming vs shoaling.

The results demonstrated that there was a: 1) significant decrease in the number of agonistic interactions at higher stocking densities, 2) significant increase in the time spent shoaling at higher densities, 3) significantly greater growth at higher stocking densities, and 4) significantly reduced level of variance at high stocking densities. These data suggest the increased growth and decreased variance may be due to a breakdown of the aggression-based dominance hierarchy. This would allow fish within the group to expend available energy on growth rather than swimming and agonistic interactions.



Figrue I: Mean standard fork length (cm) of each stocking density plotted for each biweekly measurement. N = 23 (75 fish/tank), N = 45 (150 fish/tank) and N = 90 (300 fish/tank).

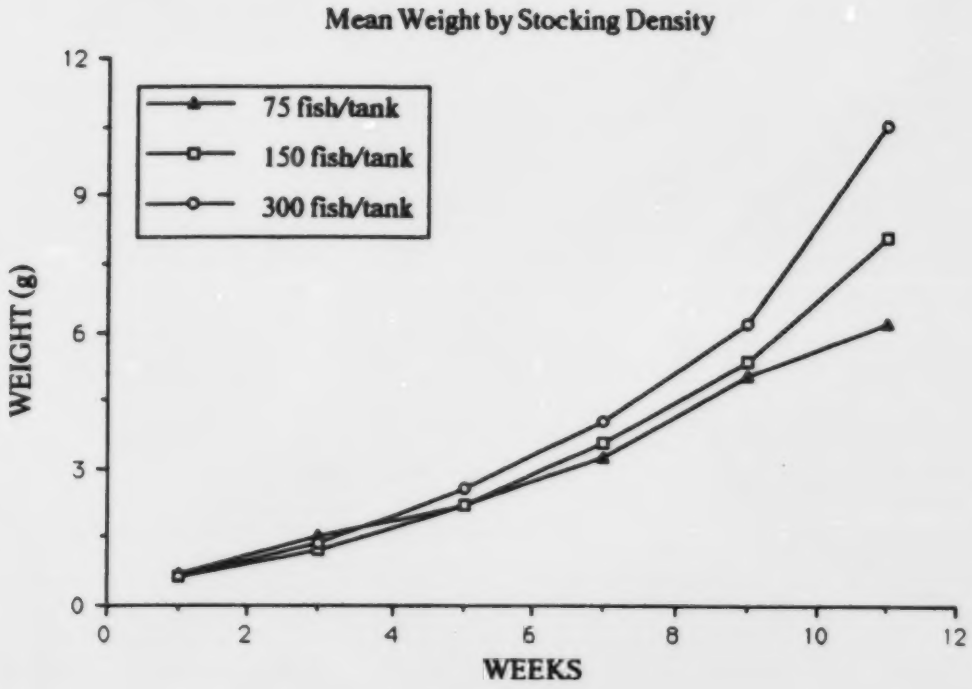


Figure II: Mean weight (g) of each stocking desnity plotted for each biweekly measurement. N = 23 (75 fish/tank), N = 45 (150 fish/tank) and N = 90 (300 fish/tank).

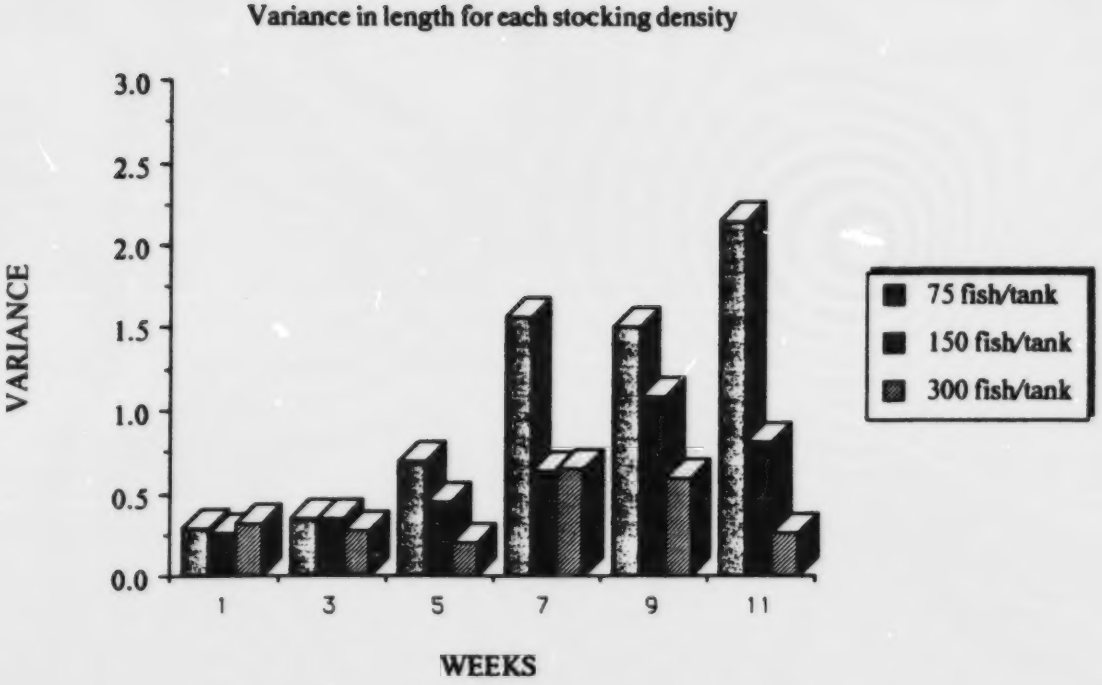


Figure III: Variance in mean standard fork length (cm) plotted for each biweekly measurements. N = 23 (75 fish/tank), N = 45 (150 fish/tank) and N = 90 (300 fish/tank).

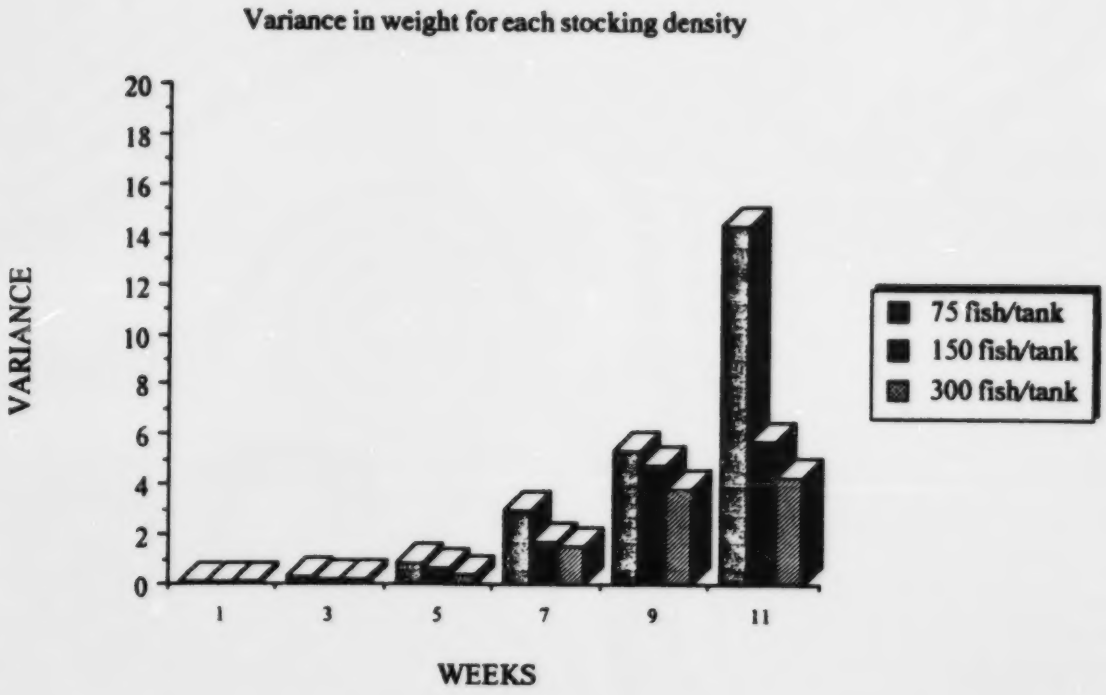


Figure IV: Variance in mean weight (g) plotted for each biweekly measurements. N = 23 (75 fish/tank), N = 45 (150 fish/tank) and N = 90 (300 fish/tank).

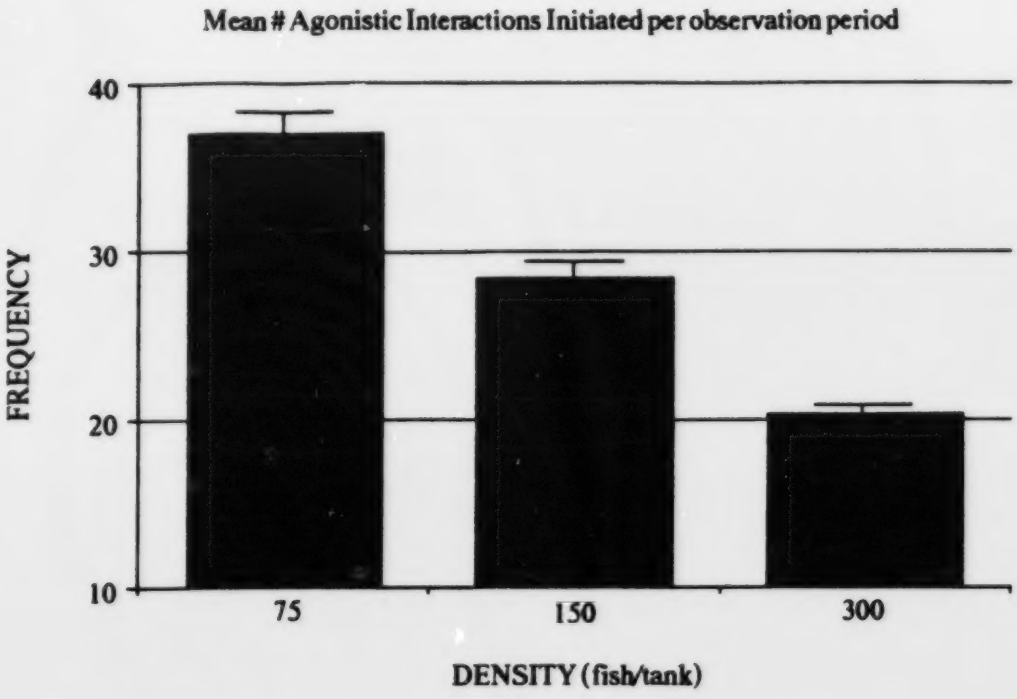


Figure V: Mean number of agonistic interactions intitated per focal animal per observation period plotted for each stocking density. Vertical bars = 1 standard deviation, N = 160.

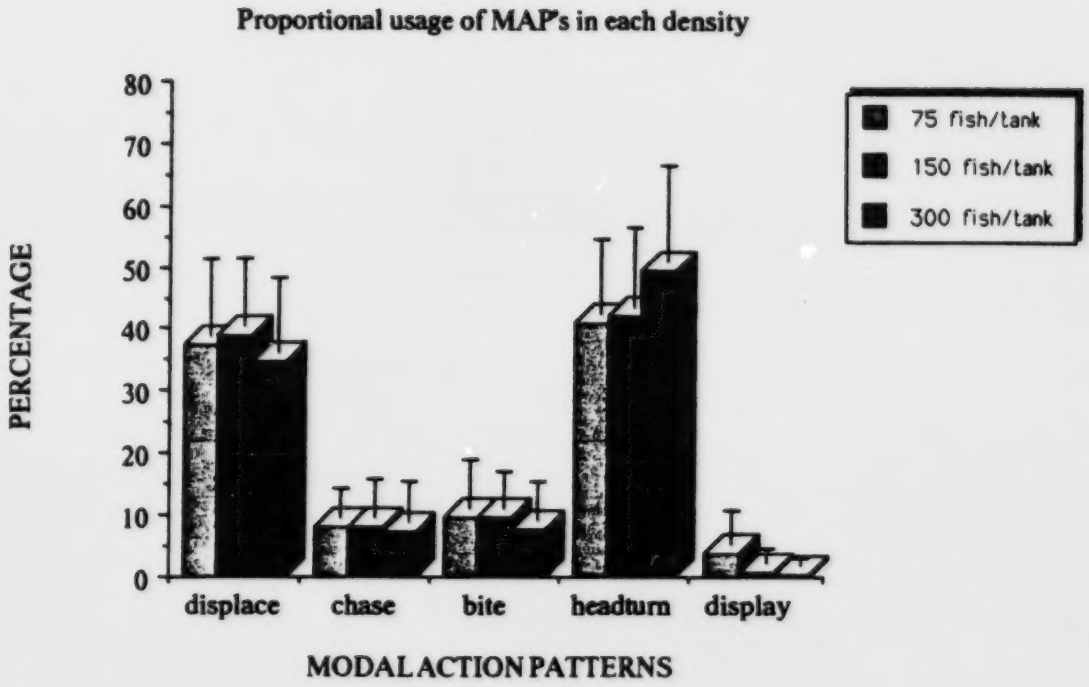


Figure VI: Mean proportional use of each Modal Action Pattern plotted for each stocking density. Vertical bars = 1 standard deviation, N = 160.

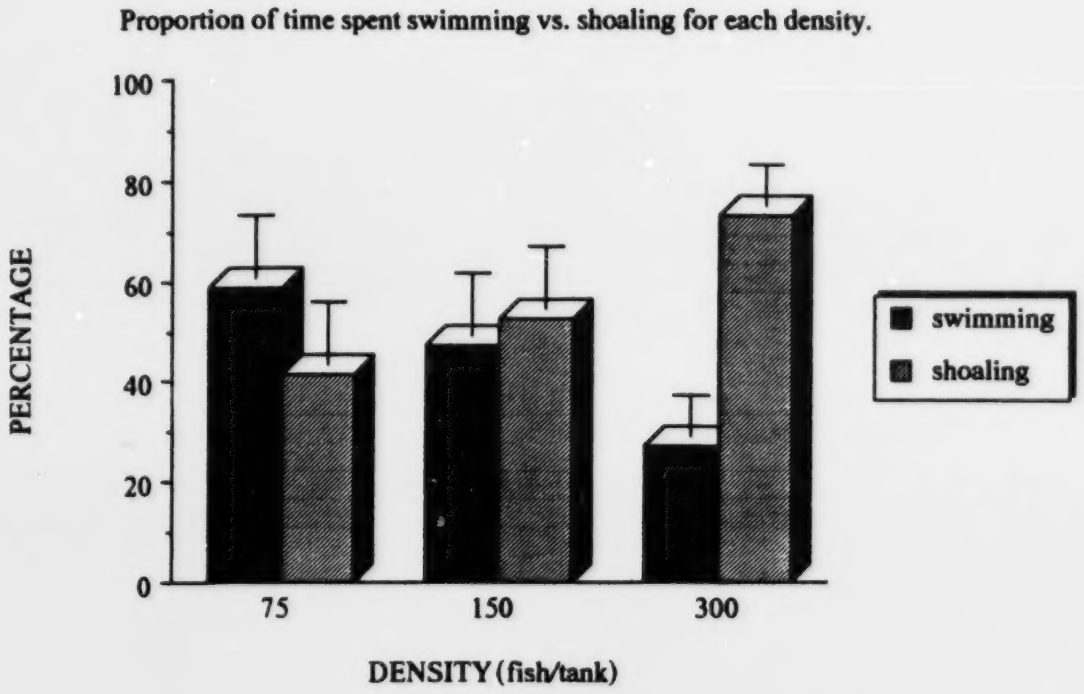


Figure VII: Mean proportion of time spent swimming vs. schoaling plotted for each stocking density. Vertical bars = 1 standard deviation, N = 160.

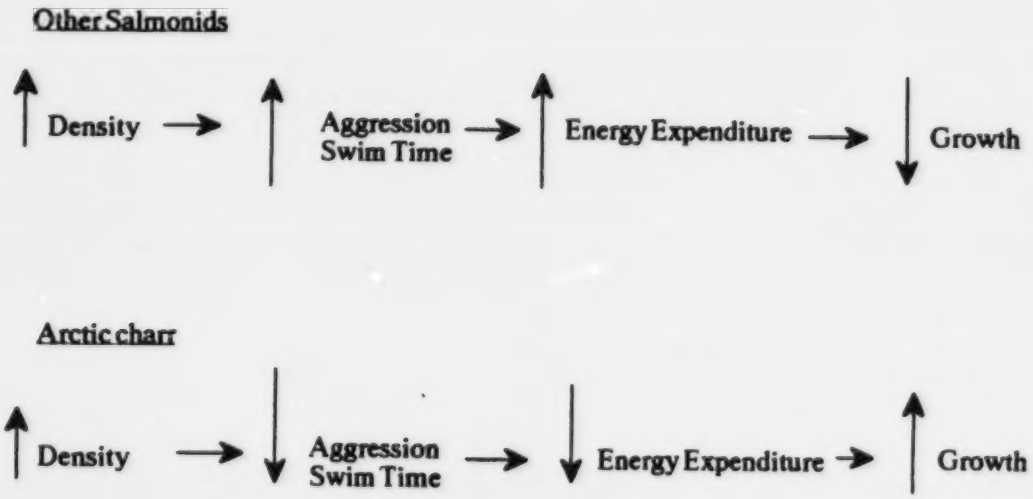


Figure VIII: Hypothesized model of energy saving resulting in greater, more homogeneous growth at high stocking densities.

SEASONAL CHANGES IN EGG QUALITY OF ARCTIC CHAR, *SALVELINUS ALPINUS* L.*

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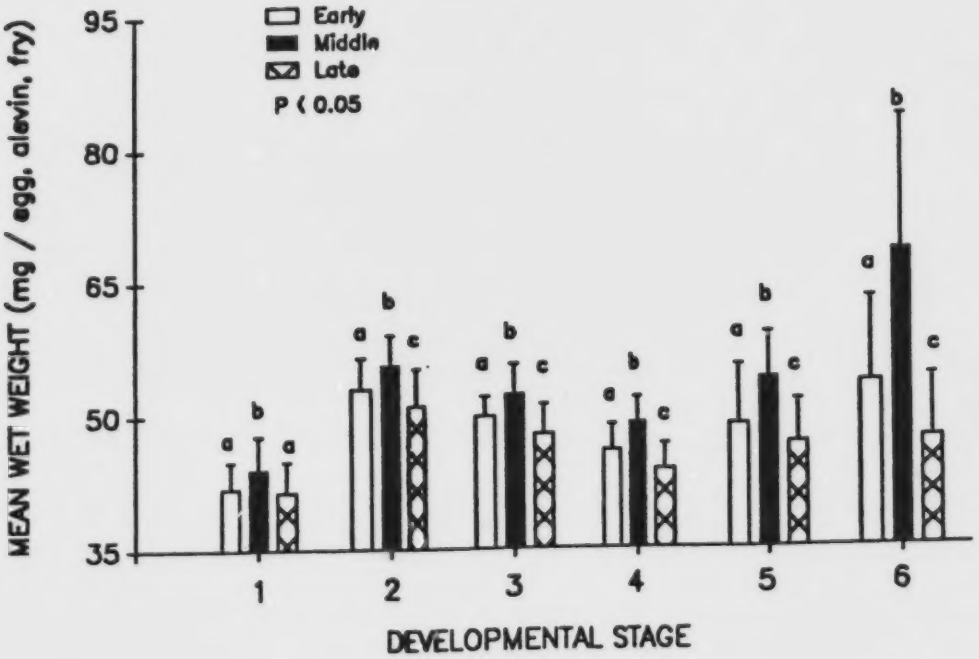
This paper deals with possible morphological, biological, and biochemical indicators of egg quality. In addition, eggs were collected at three times (early, middle, and late) over the spawning season to determine the seasonal changes in egg quality of laboratory-reared Arctic charr, *Salvelinus alpinus*. Levels of protein, lipid, carbohydrate, dry matter, ash, total and free amino acids were determined and compared to egg size, yolk-sac volume at hatching, length and weight of alevins at hatching, growth and survival to one month after first feeding.

Eggs collected in the middle of the spawning season had the higher biochemical nutrient composition which was correlated to greater growth and survival than eggs collected early or late season. The total amino acid pool and total caloric value decreased during embryonic development. The data obtained suggest that protein, lipid, carbohydrate, and amino acids were used as substrates for energy production during development. Serine, valine, tryptophan, lusine, isoleucine, and threonine were important for growth and survival of embryos and alevins.

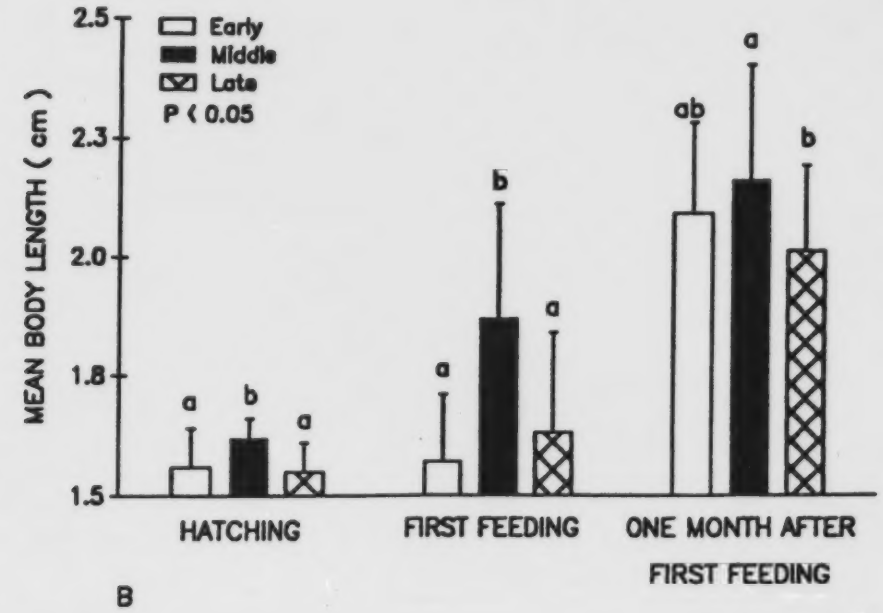
It is suggested that energy level and/or amino acid content of eggs could be used as a condition index for the future development, growth, and survival of embryos and alevins of Arctic charr.

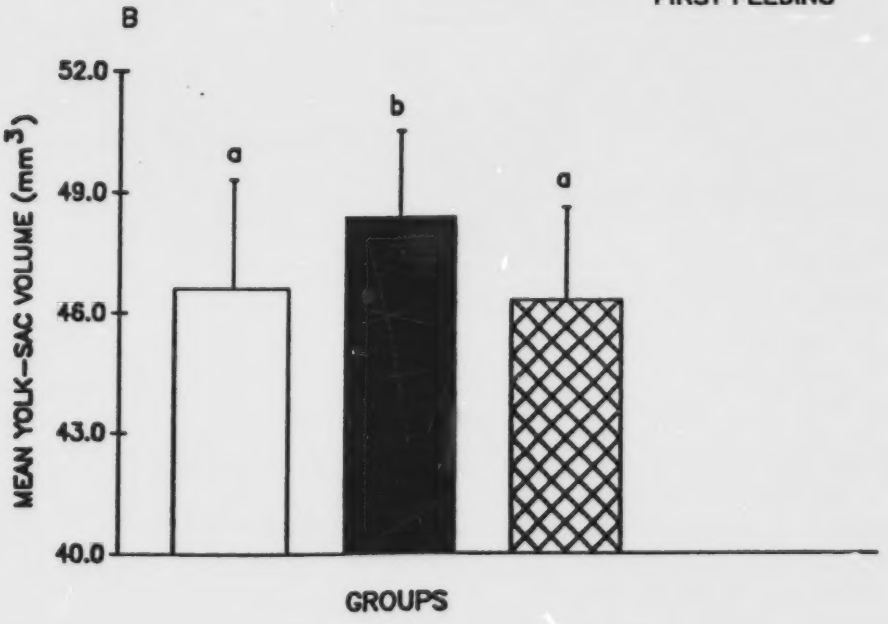
* Ocean Sciences Center Contribution Number 110.
' Present address: Department of Zoology, University of Guelph, Guelph, Ontario, N1G 2W1, Canada.

Mean wet weight (mg) of egg, alevin or fry at different stages of development for eggs collected during the early, middle and late spawning season. 1 = before fertilization, 2 = after fertilization, 3 = eyed-stage, 4 = hatching, 5 = first feeding, 6 = one month after first feeding. Values are means ± SD, n = 40. Bars with same letter are not significantly different, $P < 0.05$.

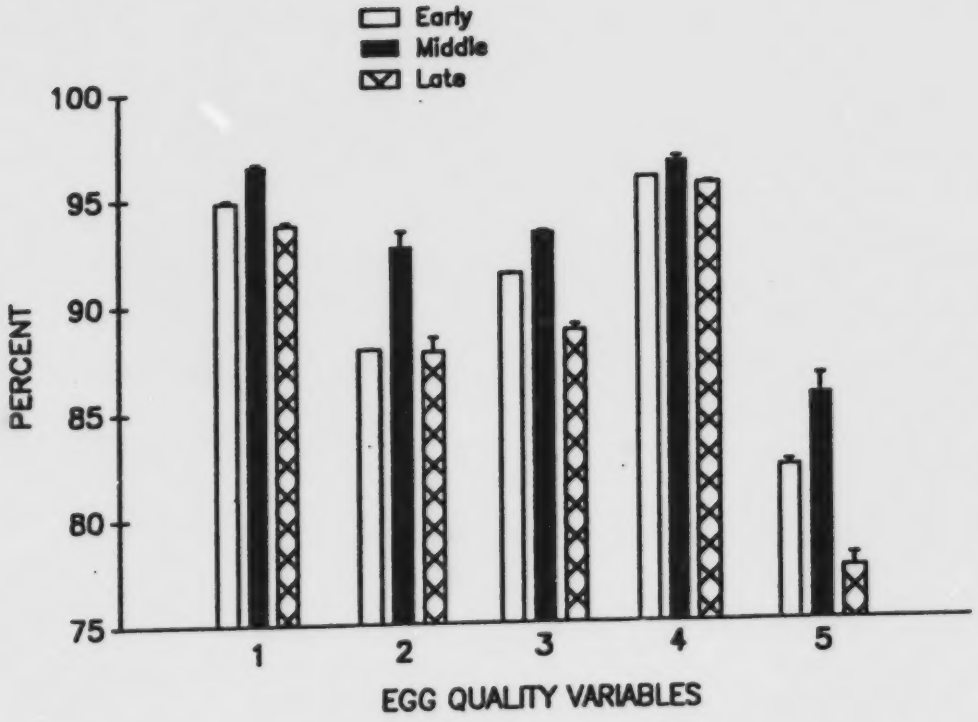


Mean body length (cm) at different stages of development. (B) Mean yolk-sac volume (mm^3) at hatching for early, middle and late groups. Symbols and histograms as in Fig. 1.

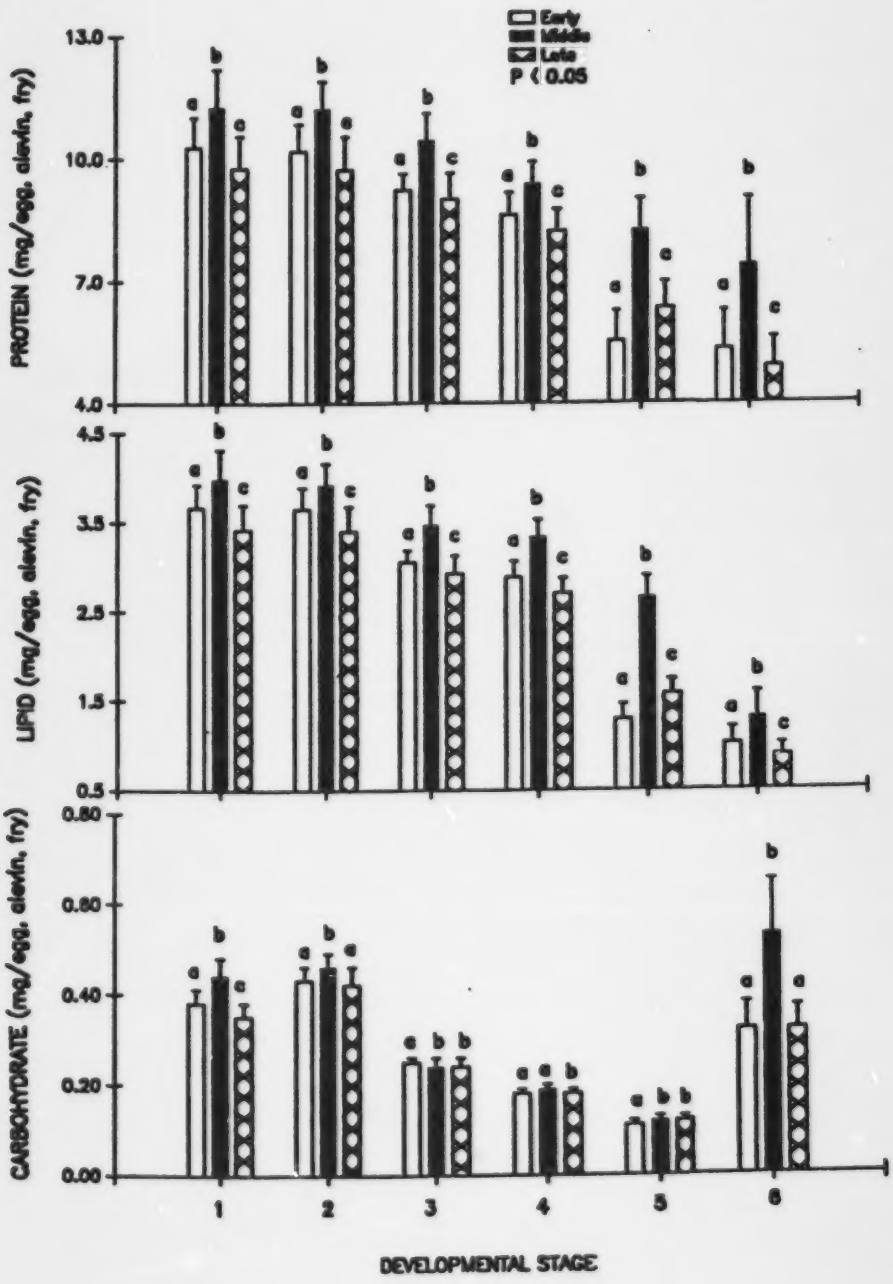




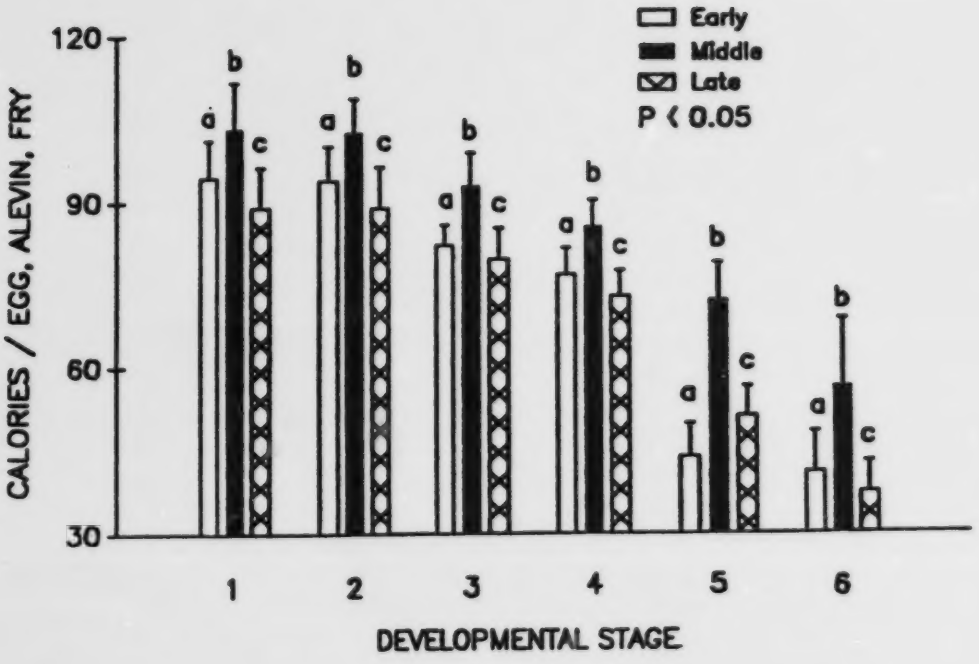
Survival (percent) at various stages (from previous stage to present stage) of development for eggs collected during the early, middle and late spawning season. 1 = fertilization success, 2 = survival to eyed-stage, 3 = survival to hatching, 4 = survival to first feeding, 5 = survival to one month after first feeding. Values are means ± SD.



Changes in the protein, lipid and carbohydrate content (mg / egg, alevin, fry) at different stages of development. 1 = before fertilization, 2 = after fertilization, 3 = eyed-stage, 4 = hatching, 5 = first feeding, 6 = one month after first feeding. Values are means ± SD, n = 40. Bars with same letter are not significantly different, $P < 0.05$. Symbols and histograms as in Fig. 1.



Changes in the energy content (calories / egg, alevin, fry) at different stages of development. 1 = before fertilization, 2 = after fertilization, 3 = eyed-stage, 4 = hatching, 5 = first feeding, 6 = one month after first feeding. Values are means ± SD, n = 40. Bars with same letter are not significantly different, $P < 0.05$.



Levels of free amino acid (nmoles / egg, alevin, fry) at different developmental stages of Arctic charr stripped in the middle of spawning season. 1 = before fertilization, 2 = after fertilization, 3 = eyed-stage, 4 = hatching, 5 = first feeding, 6 = one month after first feeding, * = essential amino acids.

Amino Acid	Developmental Stages					
	1	2	3	4	5	6
Alanine	29	12	49	588	413	774
Arginine*	10	5	73	153	167	127
Asparagine	21	16	22	12	7	0
Aspartic acid	19	11	33	333	219	35
Cysteine eq.	267	167	123	71	59	19
Glutamic acid	62	32	86	438	357	676
Glutamine	71	43	36	165	144	23
Glycine	19	10	29	447	433	614
Histidine*	10	4	31	146	122	156
Isoleucine*	13	6	30	246	130	225
Leucine*	24	10	39	419	227	430
Lysine*	16	7	89	451	350	292
Methionine eq.*	9	4	22	170	86	180
Phenylalanine*	10	7	50	212	135	179
Proline	15	6	18	397	199	250
Serine	18	10	49	517	362	279
Threonine*	11	6	21	238	172	274
Tryptophan	2	1	14	38	31	30
Tyrosine*	9	4	29	147	83	18
Valine*	17	9	39	352	206	340
Essential	130	62	423	2534	1677	2221
Non-Essential	521	307	459	3007	2224	2700
Total	651	369	882	5541	3901	4921

SOME EXPERIENCE WITH ARCTIC CHARR COMPARED WITH ATLANTIC SALMON AND RAINBOW TROUT AT THE BAY D'ESPOIR SALMON HATCHERY, NEWFOUNDLAND

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The Bay D'Espoir facility is a warm water hatchery (using hydroelectric cooling water) designed for the production of one year old Atlantic salmon smolts and 6 month old rainbow trout smolts to supply the local cage culture industry. Subsequent grow-out is conducted in an estuarine environment that is highly stratified with respect to temperature and salinity, and the temperatures beneath the ice in the winter is above lethal levels permitting the year round production of salmonids.

Arctic charr eggs (Fraser R. Stock) were imported from New Brunswick and Manitoba in 1989 and their performance was compared to that of all-female triploid rainbow trout and Atlantic salmon (St. John R. Stock, N.B.) under the prevailing conditions at both the hatchery and in pens at an estuarine farm; the intent being the possible production of charr in the 2kg range.

Charr eggs were incubated at 6°C. After hatch, the temperature was raised gradually to 10°C at first feeding compared with 10 and 14°C for rainbow trout and 8 and 14°C for the salmon. Mortalities in the charr were higher than in the salmon and the trout at all stages of development, with losses in the charr particularly elevated at hatching and later with the development of the pin head condition during early feeding. Survival to a size of 4 gram fish was 28%, 70% and 75% for the char, salmon and trout respectively. The relatively small egg size of charr could have been a contributing factor. Incident light of an intensity having no effect on salmon or trout was found to inhibit the initiation of first feeding in char.

The charr were kept on cooled water (14°C) during their first summer at the hatchery. While survival was good, growth rates were intermediate between that of salmon and trout, the later groups being held under water considerably warmer (18.5°C maximum). The densities in the rearing tanks holding the charr were low (no greater than 25 kg/cubic meter) and were probably not optimum.

In the fall 6000 charr (60-80 grams) were stocked into fish pens at Roti Bay, and their survival and growth rates under the ice during the winter were somewhat better than that of salmon and comparable to the trout. There was no problem in buoyancy regulation (access to surface air and swim bladder inflation) that

is commonly observed in the salmon that are held under the ice.

The charr resumed feeding in the spring, but as warm surface temperatures developed in July they appeared to remain deeper in the water column than the trout and salmon, avoided the warm surface water and never exhibited the surface feeding frenzy typical of the trout. Their food intake was therefore difficult to determine. Larger charr equipped with internal sonic tags transmitting body temperature, revealed that the charr selected a narrow range of temperature in the thermocline of 13.4°C in July and avoided the cooler, deeper more saline water. The charr appeared to regulate body temperature more precisely than the trout, although the preferred temperature of the two did not differ significantly.

The growth of the charr throughout the summer was inferior to that of both the salmon and the trout; as none of the three species sexually matured this was not a complicating factor. The charr experienced two outbreaks of vibriosis (that were apparently brought under control with an antibiotic) despite having been vaccinated twice prior to stocking. A similar treatment of the trout was also necessary.

A group of 8000 charr yearlings that were retained at the hatchery as potential brood fish, were held the second summer on water that was not cooled. As temperatures exceeded 15°C, a series of outbreaks of furunculosis and septicemic bacterial infections resulted in all of the charr being eventually destroyed; however comparable sized trout in adjacent tanks were unaffected.

An examination of pan-sized charr at the hatchery and at Roti Bay revealed a large variation in their size and condition factor relative to trout. Also the hue and intensity of flesh coloration of the charr was inferior to that of the trout despite having been fed the same commercial feed containing pigment.

To eliminate the potential problem of early male maturity as a factor limiting market size, attempts to sex reverse female charr with oral feedings of methyl-testosterone at swim up using doses effective for trout, resulted in a very high level of sterile fish which suggests that either the dose or duration of treatment needs to be refined. At the present time there are sufficient numbers of normal and sex-reversed charr in the cages to supply eggs and homogametic milt should continued efforts with this species at Bay D'Espoir be desirable.

It is concluded that, under the environmental constraints prevailing at Bay D'Espoir taken together with some of the biological problems experienced with Arctic charr here and elsewhere, aspirations to include this species as part of our commercial production line should be moderated pending the availability of more promising results.

UPTAKE OF PIGMENTS IN THE FLESH OF ARCTIC CHARR DERIVED FROM PIGMENTS IN THE DIET

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Pigmentation of salmonid fish is due to the uptake and deposition of feed carotenoids. The colour of carotenoids is due to a chromophore consisting of a chain of conjugated double bonds (Figure 1). Only plants and protists are able to synthesize carotenoids. Salmonid fish, like other animals, are incapable of De Novo synthesis and acquire carotenoids from their diet. Thus, cultured salmonids require pigmented diets in order to develop adequate colour quality. While the effect of feed pigmentation has been thoroughly investigated in rainbow trout, brook trout, and coho salmon, such studies have not been reported for Arctic charr.

Arctic charr (Salvelinus alpinus), reared from eggs and fed on Corey dry Salmon Grower diet (Corey Feed Mills, Fredericton, New Brunswick) were about 20 months old and weighed 519 ± 390g at the start of these experiments. Four experimental groups, in separate 1.7m diameter circular tanks were fed formulated, capelin-based, moist feed pellets containing (a) about 75 ppm astaxanthin or (b) canthaxanthin, obtained from shrimp shell waste and spiked by a commercial sample or (c) raw shrimp shell waste. The fourth group, used as a control, was fed a commercial dry pellet containing both astaxanthin and canthaxanthin (40:60, w/w) pigments.

The uptake of pigments in both the flesh and skin of the charr was monitored over a 15-week period. All groups, except for the fish on the diet containing raw shrimp shell waste, showed adequate pigmentation after a 9 week feeding period. The pigmentation in the latter group occurred mainly in the skin. It appears that Arctic charr first absorb carotenoids in their skin and, after development of sufficient skin pigmentation, carotenoids are deposited in their flesh (Table 1). Thus, the total carotenoid content in the skin of Arctic charr was about 10 times higher than that in the flesh.

The total carotenoid content in the flesh corresponded well with the development of a reddish muscle colour, as measured by their Hunter a values (Table 2). Correlation coefficients between Hunter a values and total carotenoid content in the flesh of charr in the different groups was always ≥ 0.916.

Table 1. Total Carotenoids (μg/g) in the flesh and skin of Arctic char.

Feeding Period, weeks	Feed containing[a]			
	Shrimp waste	Astaxanthin	Canthaxanthin	Commercial Feed
	Arctic Char Flesh			
0	1.35 ±0.06	1.35 ± 0.06	1.35 ± 0.06	1.35 ± 0.06
5	1.59 ± 0.09	2.55 ± 0.41	3.79 ± 0.33	3.54 ± 0.14
9	1.07 ± 0.59	4.10 ± 0.06	4.86 ± 0.24	4.43 ± 0.12
15	7.14 ± 0.16	5.56 ± 0.11	5.78 ± 1.18	6.17 ± 0.66
	Arctic Char Skin			
0	10.73 ± 0.32	10.73 ± 0.32	10.73 ± 0.32	10.73 ± 0.32
5	14.63 ± 0.13	14.86 ± 0.18	15.36 ± 1.01	13.53 ± 1.97
9	18.42 ± 0.32	36.01 ± 1.57	15.56 ± 1.49	18.46 ± 1.10
15	18.23 ± 1.56	41.21 ± 2.27	32.92 ± 3.42	21.27 ± 1.94

[a] Feeds contained 75 ppm pigments except those on shrimp waste which had only 7.2 ppm carotenoids.

Table 2. Hunter a values of Arctic char flesh during a 15-week feeding period.

Feeding Period, Weeks	Hunter a value[a]			
	Shrimp waste	Astaxanthin	Canthaxanthin	Commercial Feed
0	1.20 ± 0.37	1.20 ± 0.37	1.20 ± 0.87	1.20 ± 0.37
5	4.11 ± 1.05	8.03 ± 1.36	13.42 ±1.80	11.51 ± 1.23
9	1.67 ± 0.76	14.13 ± 0.62	15.45 ± 0.89	12.02 ± 1.30
15	2.46 ± 1.04	17.44 ± 0.66	18.23 ± 1.72	14.87 ± 1.17

[a] Feeds contained 75 ppm pigments except those on shrimp waste which had only 7.2 ppm carotenoids.

FIRST YEAR HATCHERY GROWTH OF AN ARCTIC CHARR POPULATION, 1989-90 AT NAFC

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Arctic charr, Salvelinus alpinus, Fraser River, Labrador stock, were raised through their first year at the Northwest Atlantic Fisheries Center, St. John's. Start feeding commenced the first week of March, 1989, using a mixture of Biodiet and No. 0.5 Corey Starter diet followed by Corey dry Salmon Grower, at sizes appropriate for the size of the fish, as they grew. Fish were fed to satiation (subjectively defined by their loss of interest in striking the food particles) twice daily during the week and once per day on weekends. Temperatures during culture averaged about 10.5°C. Fork length and weight measurements were taken at age 9 months and at age 1 year.

At age 9 months, the population's mean length and weight were 12.5 cm. and 24.0 g. respectively. At age 1 year, the mean length and weight were 19.9 cm. and 106.6 g. respectively. Considerable variation in both length and weight was evident at both 9 months of age and at 1 year (Figures 1 & 2).

During the interval from age 9 months to 1 year, the gross food conversion efficiency, expressed as the ratio:

$$\text{Gross C. E.} = \frac{\text{dry weight of food provided}}{\text{net weight gain of fish (wet weight)}}$$

was 1.05. This value indicates an excellent feed to fish body weight conversion. Since feed costs represent a large proportion of total production costs in intensive aquaculture systems, conversion efficiency values close to 1 are economically very important.

By age 1 year, a large variation in body condition or "robustness", expressed as wet weight / length^3, was also evident (Figure 3). Some fish were quite deep-bodied for their length while others were more slender.

The observed variation in growth rate and body proportions will have a significant effect on commercial production operations, if they persist at market size. De March (1991) has determined that the variation in both growth and condition is genetically based in Arctic charr. The size variations during growout will necessitate

fish grading before harvest, possibly on more than one occasion, with appropriate changes in the size of food pellets provided throughout. Papst and Hopky (1984) found that, even with grading into separate tanks, the growth rate of small fish did not significantly improve. A proportion of the population may never reach market size (Papst and Hopky 1989). Variations in body proportions will significantly impact on perceived product quality and/or market price since uniformity in size of both the whole fish and the fillets is an important marketing consideration.

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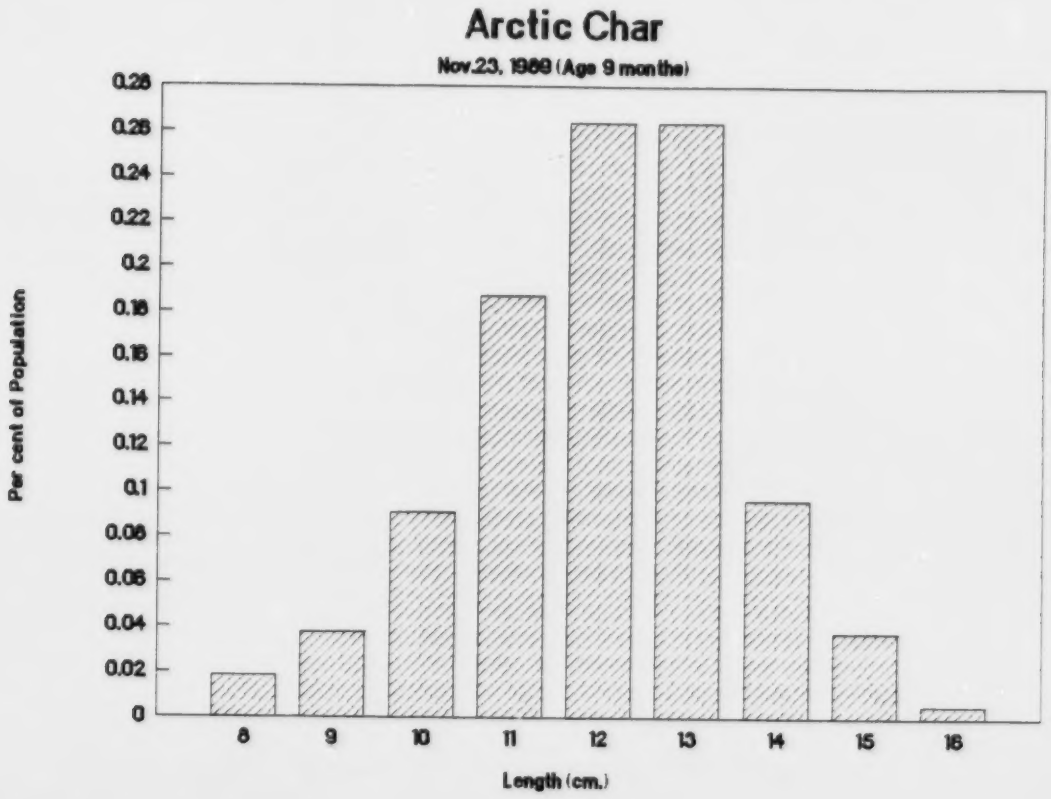


Figure 1a. Fork length of Arctic char at age 9 months

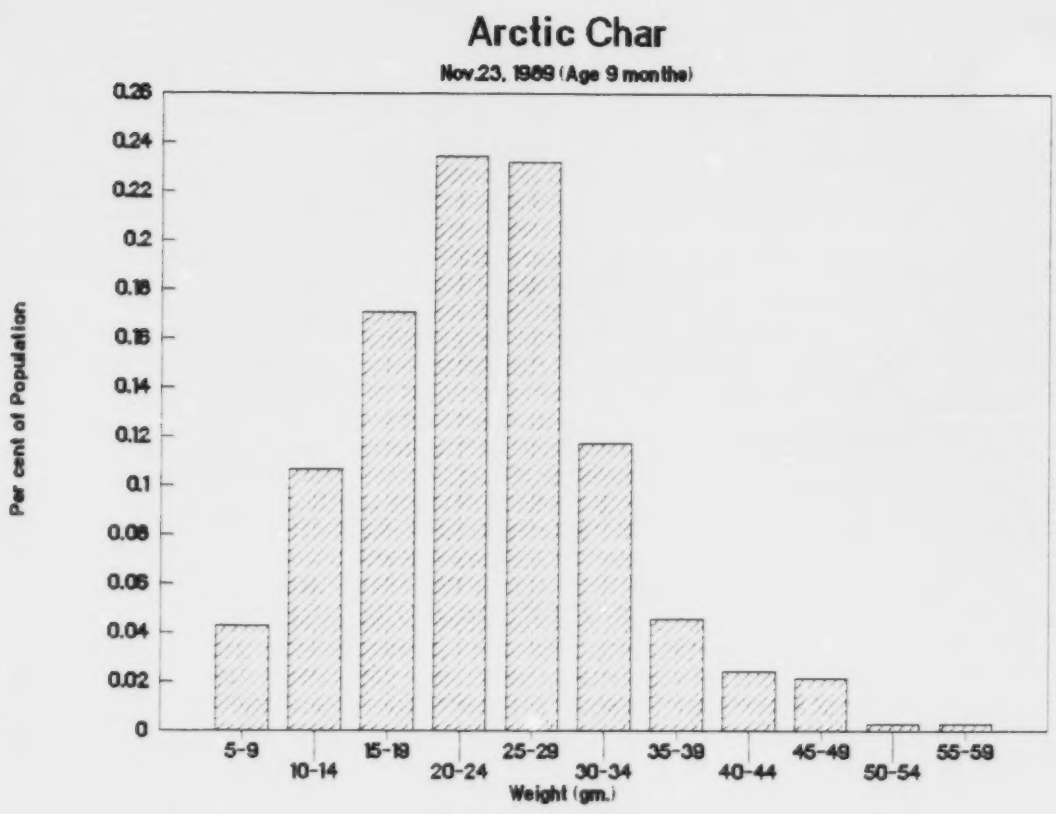
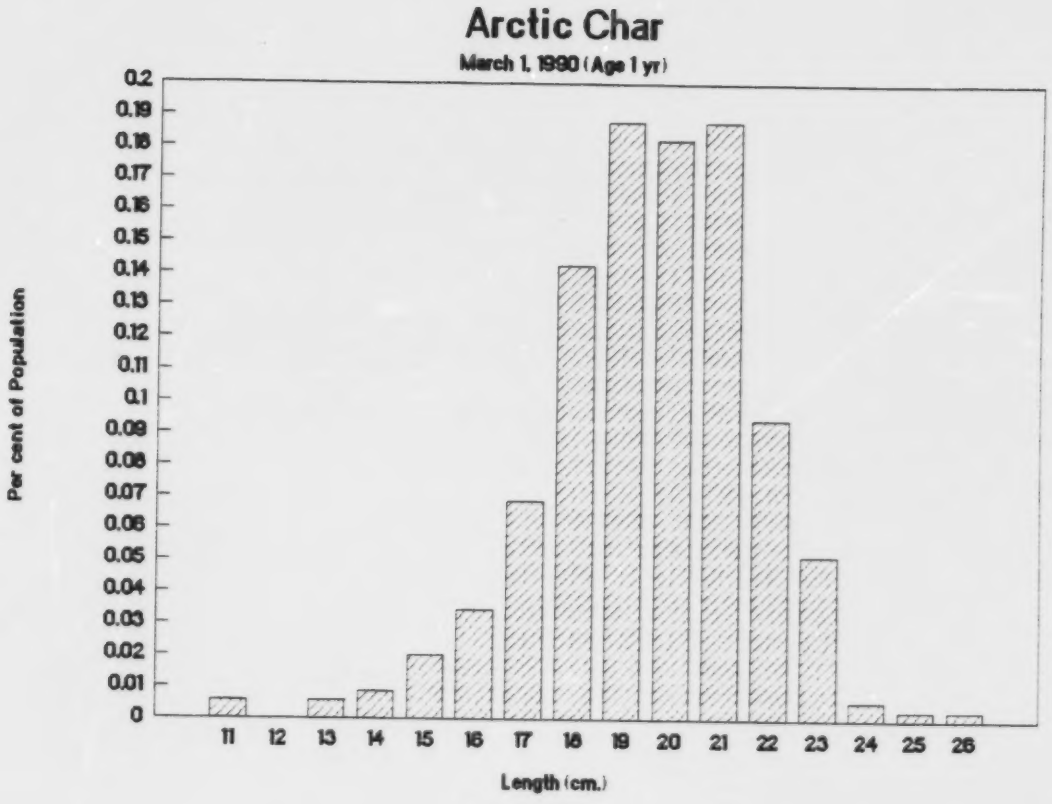


Figure 1b. Wet weight of Arctic char at age 9 months.



Fifure 2a. Fork length of Arctic char at age 1 year.

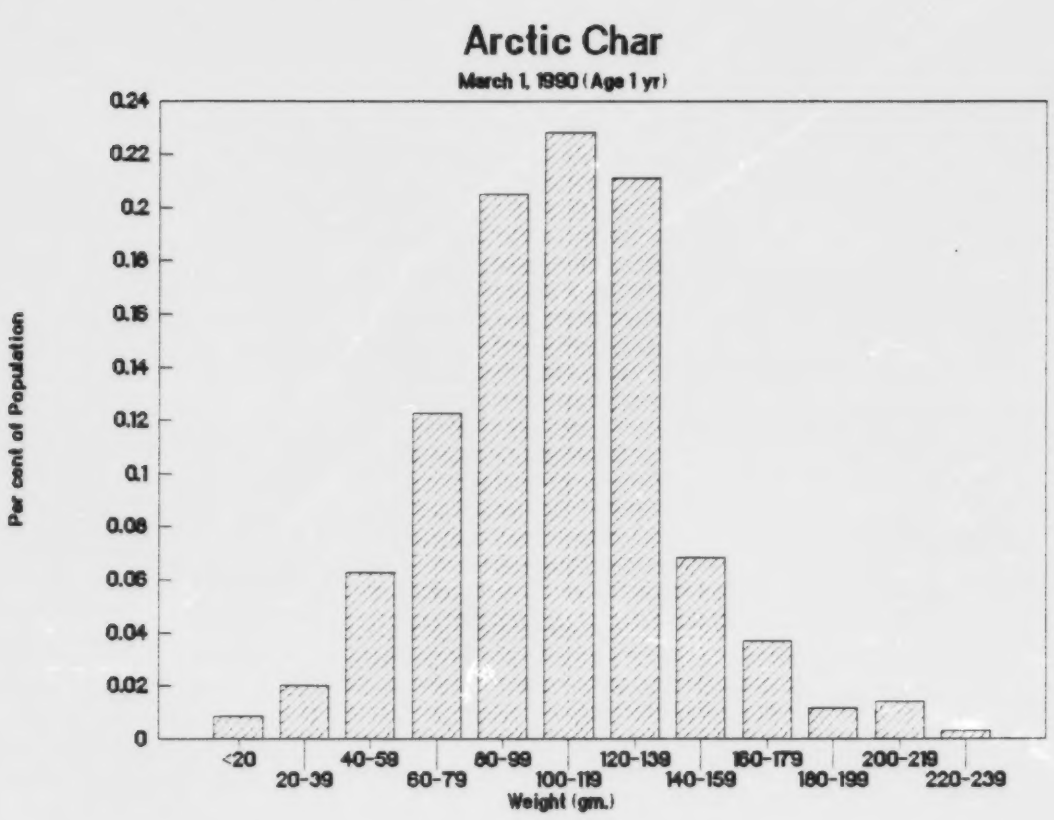


Figure 2b. Wet weight of Arctic char at age 1 year.

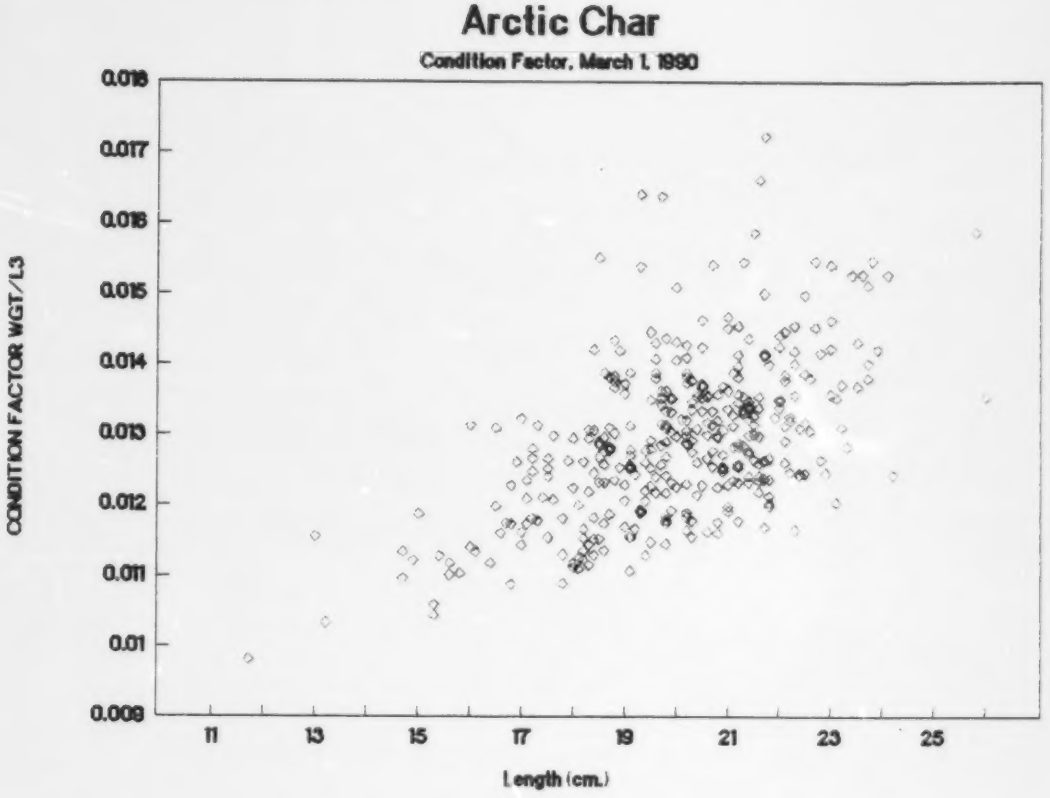


Figure 3. Condition factors, expressed as wetweight/fork length cubed, for Arctic char at age 1 year.

WILD ARCTIC CHARR POPULATIONS IN NEWFOUNDLAND AND LABRADOR

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Background

Research investigations on Arctic charr populations in the Newfoundland Region have primarily been associated with aspects related to the commercial fishery for anadromous charr in northern Labrador (Figure 1). These studies have focused on population dynamics of exploited stocks, stock identification studies, and various stock specific life history investigations.

Information derived from morphological studies, differences in biological characteristics, and from studies examining movement patterns and migrations resulted in the derivation of several stock units or complexes along the northern Labrador coast (Figure 2). The present commercial fishery for Arctic charr in this area is managed on this stock unit basis.

Commercial Production of Arctic charr

Figure 3 illustrates the commercial landings of anadromous Arctic charr from the northern Labrador coast from 1944-90. Highest landings occurred in 1981 when approximately 250 tonnes were caught. Since then, there has been a radical decline in commercial catches with landings in the last few years of about 100 tonnes. Some of the decline in catches can be accounted for by a reduction in the amount of fishing effort directed towards the fishery. Landings with respect to total allowable catches for three stock units are summarized in Figure 4. A comparison of commercial landings of anadromous Arctic charr from Labrador and the Northwest Territories is provided in Figure 5 for the period since 1970.

Distribution

Arctic charr are widely distributed within the Newfoundland Region. Figures 6 & 7 illustrate the general distribution of confirmed populations for Labrador and insular Newfoundland respectively. While anadromous forms are common in Labrador, some anadromous populations of charr are also known to exist in the insular portion of the province. On the island, charr are more commonly found in deeper ponds. Studies on the spatial and temporal usage of lacustrine habitat by salmonids have shown that Arctic charr can be found in both the pelagic and benthic regions of ponds.

Characteristics of populations

Most of the populations of charr that occur in insular Newfoundland are characterized by their small size and younger ages in contrast with their related forms in Labrador. Insular Newfoundland charr are generally less than 20 cm (Fig. 8) in size and with maximum ages upwards of 10 years, although exceptions do occur as in Lake Michael. Some Labrador fish have been known to reach over 80 cm in fork length and 9 kg in weight, although most of the anadromous charr caught in the commercial fishery are 48-60 cm in length and weigh an average of 2-3 kg. Ages over 20 years have been recorded in Labrador charr. Figure 9 summarizes the mean size at age in several Labrador populations of charr from samples derived from various counting fence enumeration projects. Table 1 provides a brief comparative summary of several characteristics of Arctic charr from insular Newfoundland and Labrador.

Table 2 summarizes migratory and reproductive characteristics of several Labrador charr populations in comparison with charr from other areas including northern Quebec, Northwest Territories, Alaska, and the U. S. S. R. Fraser River charr, which have been used in a wide variety of aquaculture related studies, migrate to the sea for the first time at 3-7 years of age. Size at this time ranges from about 9 to 19 cm. Mature Fraser River females were found to produce about 249 eggs per 100g of body weight or, on average, approximately 5,000 eggs for a 2 kg fish. About 60% of the fish that go to sea are females. Fecundity for the smaller insular Newfoundland charr may only be from 80 to several hundred eggs per fish. Other information on characteristics of the Fraser River population can be found in Dempson and Green (1985).

Arctic charr in northern Labrador have been found to hybridize naturally with both lake trout and brook trout. The ecological and genetic implications of this have recently been published. While meristic characteristics can be used to separate out hybrids from either of the parental species, genetic analyses provide the most conclusive evidence.

Studies comparing the lethal freezing temperature of charr with other salmonids have shown that Arctic charr have a lower fish freezing point and plasma freezing point than brook trout, brown trout, Atlantic salmon, and rainbow trout (Fletcher et al. 1989) (Figure 10). This could be important in those areas where Arctic charr may be considered for sea rearing.

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Table 1. # Summary of characteristics

Characteristic	Newfoundland	Labrador
Availability	Common & accessible	Abundant in north less accessible
Age	Most < 10 years old	Can be > 20 years
Growth	Most < 20 cm	40-70 cm; few > 70
First Maturity	2-4 years (8-15 cm)	6-9 yrs (~35-45 cm)
Flesh Colour	Pale and white	Variable by location more red in north
Sea Water Tolerance	?	St. Spec. variable
Genetic Variability	Least variable	Most variable (more in north)

Table 2. Summary of migratory and reproductive information on various anadromous Arctic charr populations

Study[a]	Location	Downstream migrants		Upstream migrants				Maturation and fecundity			
		Age at first sea migration (years)	Size at migration (mm)	Mean length (mm)	Range (mm)	Mean age (years)	Range (years)	Age at first maturity (years)	Size at maturity (mm)	Mean fecundity	Relative fecundity no. eggs per 100 g body weight
1	St. Charles River, Labrador; 52° N, 55° W	2–5		450	251–708	6.2	4–9				
2	Northwest Tributary, Sand Hill River, Labrador; 53° N, 56° W			400	187–641	5.2	2–10				
3	Middle Brook – Double Brook, Labrador; 54° N, 58° W			419	196–767	5.3	2–10				
4	Fraser River, Labrador; 56° N, 63° W	3–7	87–191	451	127–820	8.3	3–18	5(6.9)[b]	262(381)	4665	249
5	Nachvak Fiord, Labrador; 59° N, 63° W	2–6	78–115					7(10.0)	358	2876	281
6	Leaf River, Ungava Bay; 58° N, 70° W	3–7	220					6(8.0)	(500)	4397	167
7	Sylvia Grinnell River, Frobisher Bay; 63° N, 68° W	4–7	130–170	476	130–825		4–21	11	450	3465	179
8	Cumberland Sound, Baffin Island; 66° N, 67° W	5–7	114–210	562	250–750	17.2	7–20	11	392	5400	284
9	Sandy Point River, Hudson Bay; 61° N, 93° W			613	248–928	7.7	3–17				
10	Diana River, Hudson Bay; 62° N, 92° W			567	176–882	8.4	3–20				
11	Jayco River, Victoria Island, N.W.T.; 69° N, 103° W			424	209–822	9.5	3–22				
12	Nauyuk Lake, Kent Peninsula, N.W.T.; 68° N, 107° W	4–7	132–241	598	~120– ~900		5–21	10 –	620	4781	140
13	Sagavanirktok River, Alaska; 70° N, 148° W	2–5	145–195	482	210–710			6–7	481	4153	335
14	Novaya Zemla, U.S.S.R.; 74° N, 55° E	4–5	(185)	480	275–660	7–8	3–12	6–7	(463)	3507	148

[a]1, Peet (1968). 2, Peet (1971). 3, Peet (1971). 4, present study. 5, Glova and McCart (1978). 6, Lee (1969). 7, Grainger (1953). 8, Moore (1975*a*, 1975*b*). 9, Johnson (1980). 10, Johnson (1980). 11, Dahlke and Falk (1979). 12, Johnson (1980). 13, Yoshihara (1973). 14, Yessipov (1935)

[b]Values in parentheses are mean values

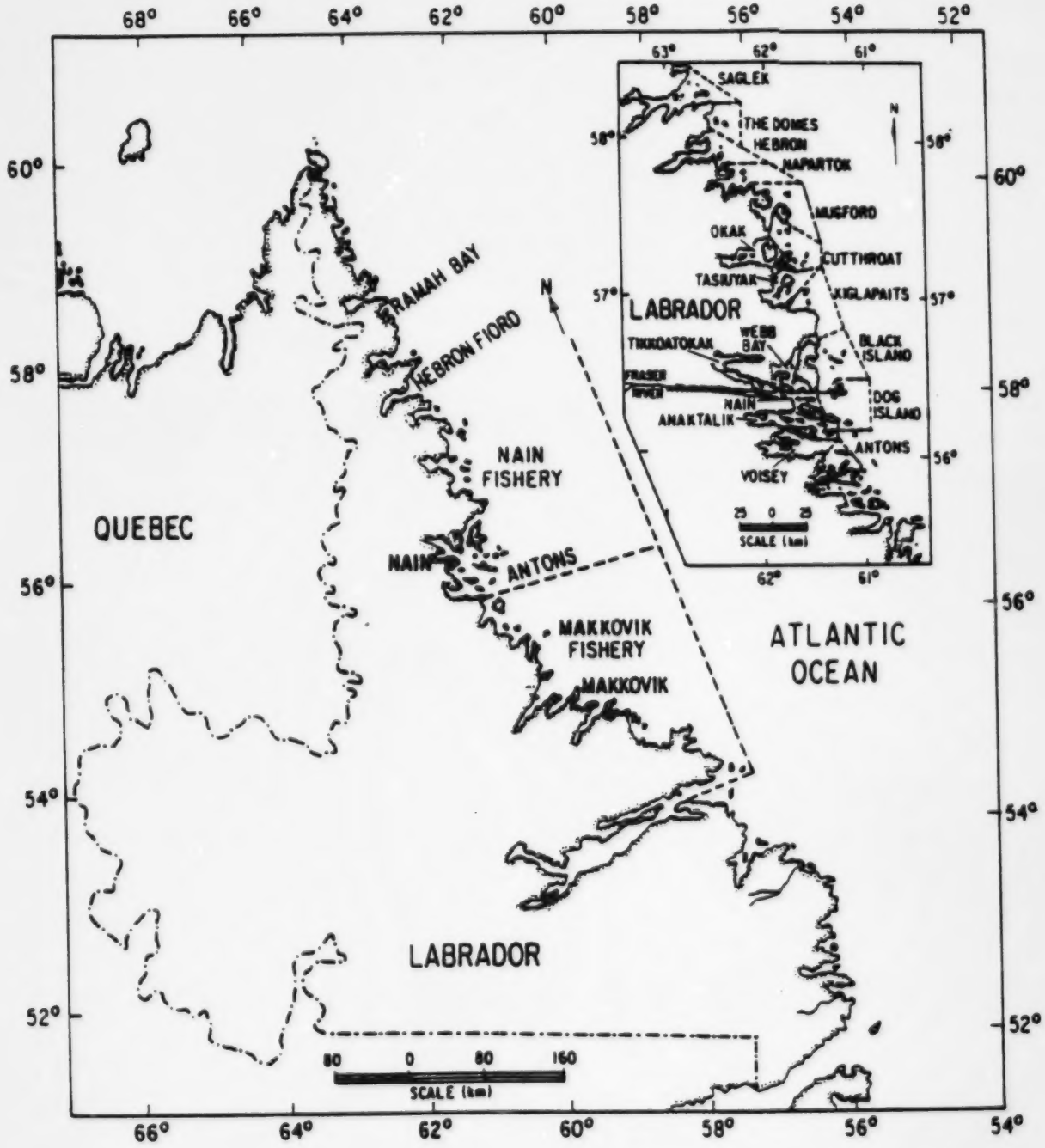


Fig. 1. Location of the Nain and Makkovik fishing regions in northern Labrador.

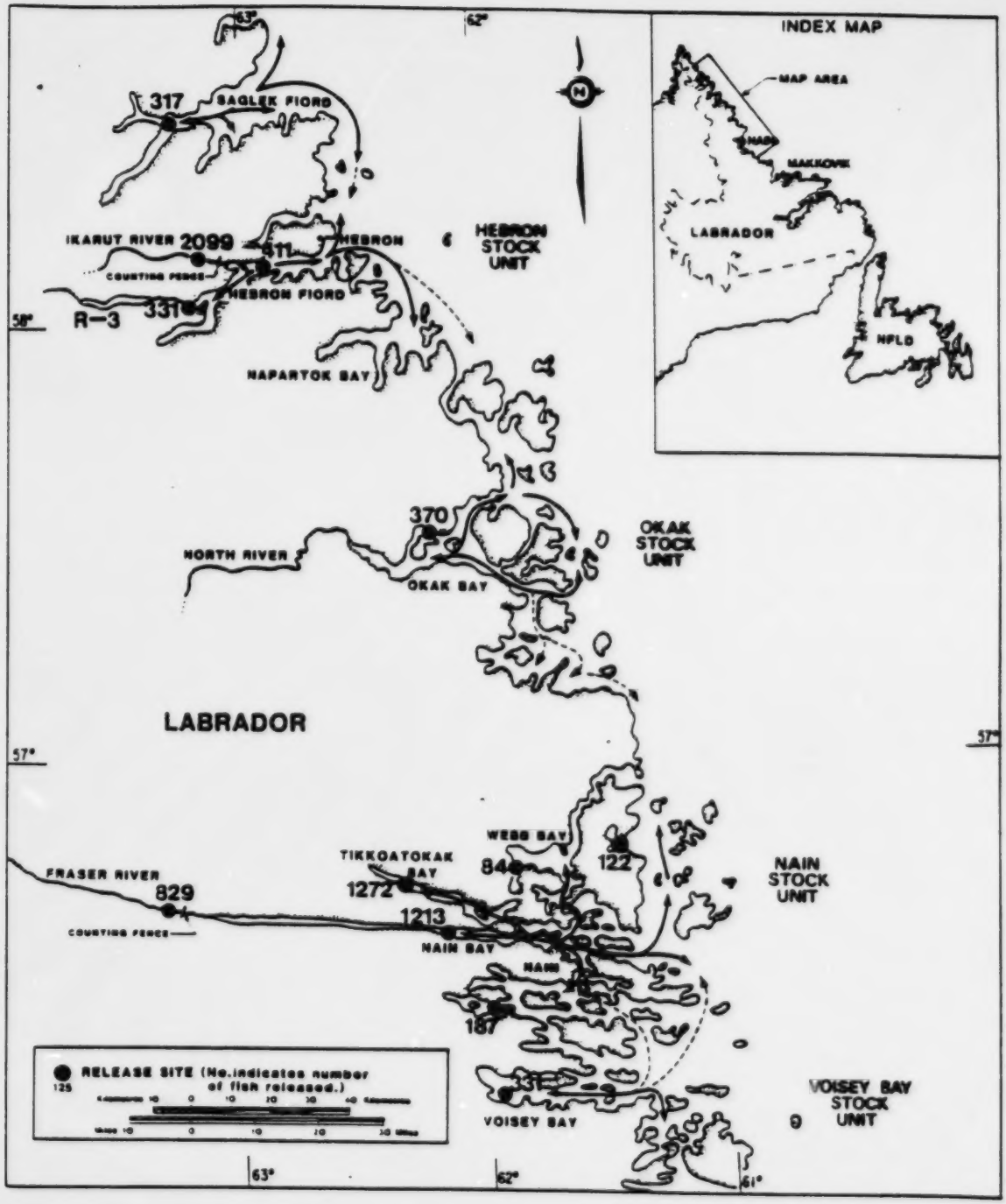


Fig. 2. Coastal migrations of various Arctic charr stocks in northern Labrador, and stock unit desigations.

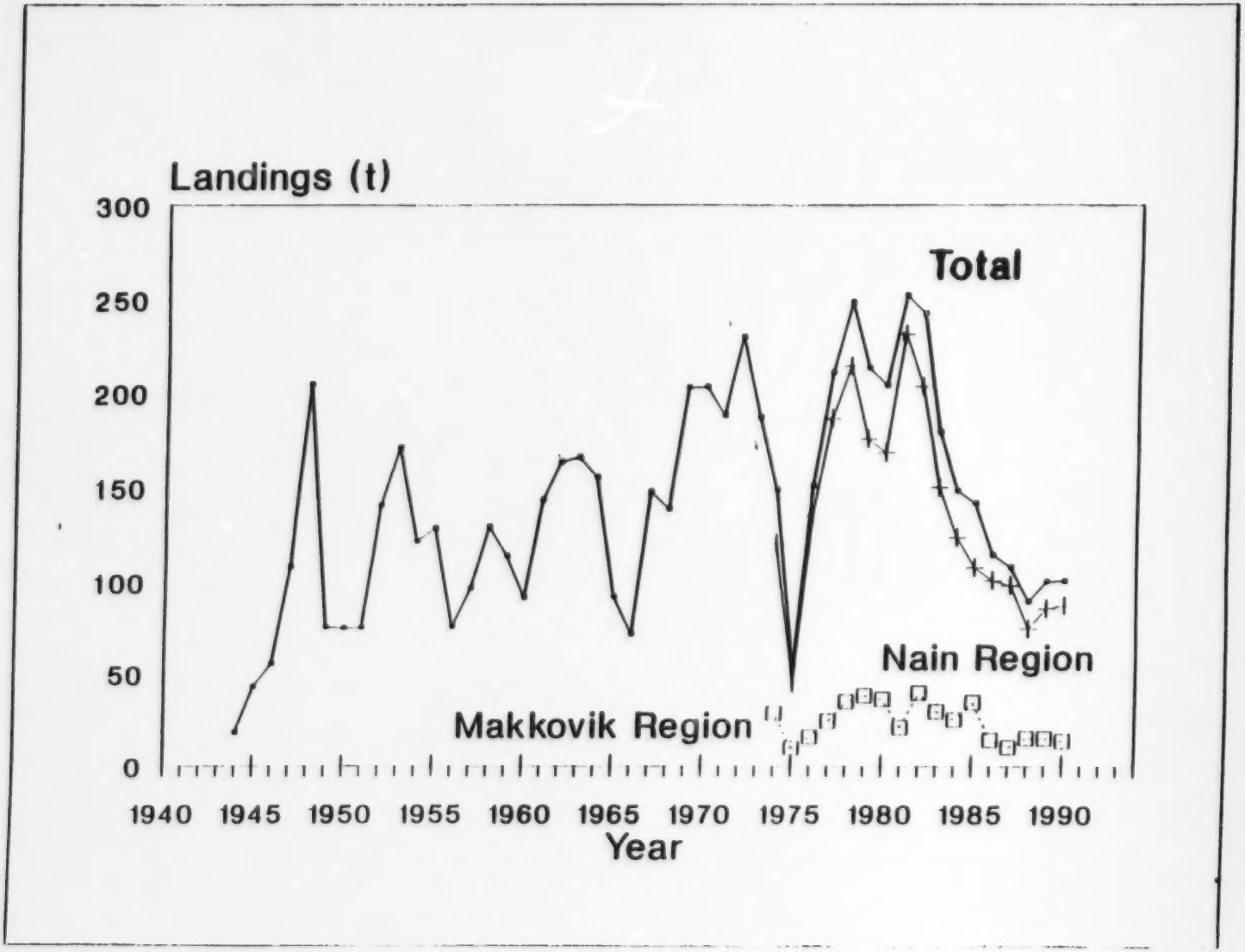
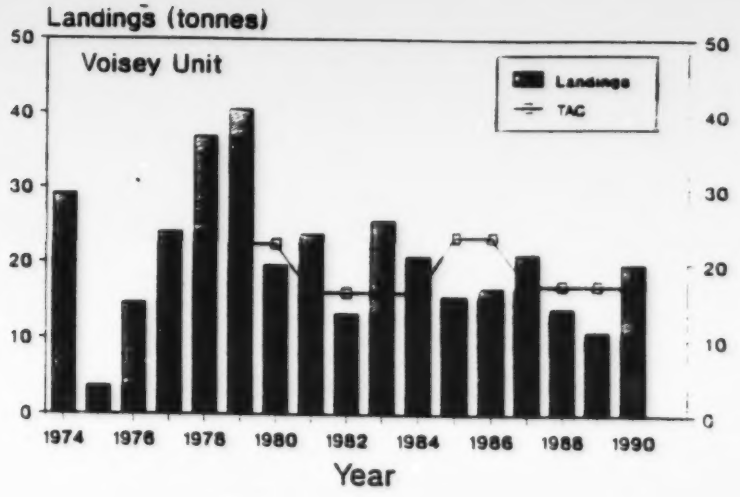
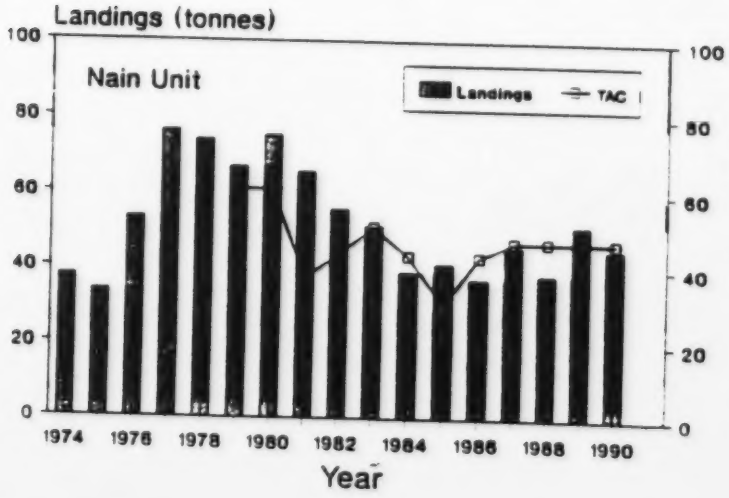


Fig. 3. Summary of northern Labrador Arctic charr landings (metric tonnes), 1944-90.





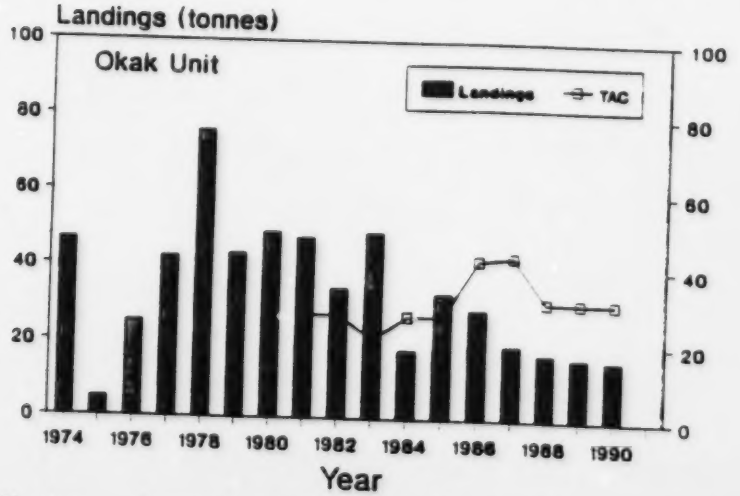


Fig. 4 Summary of total landings with respect to total allowable catch for the Voisey, Nain, and Okak stock units.

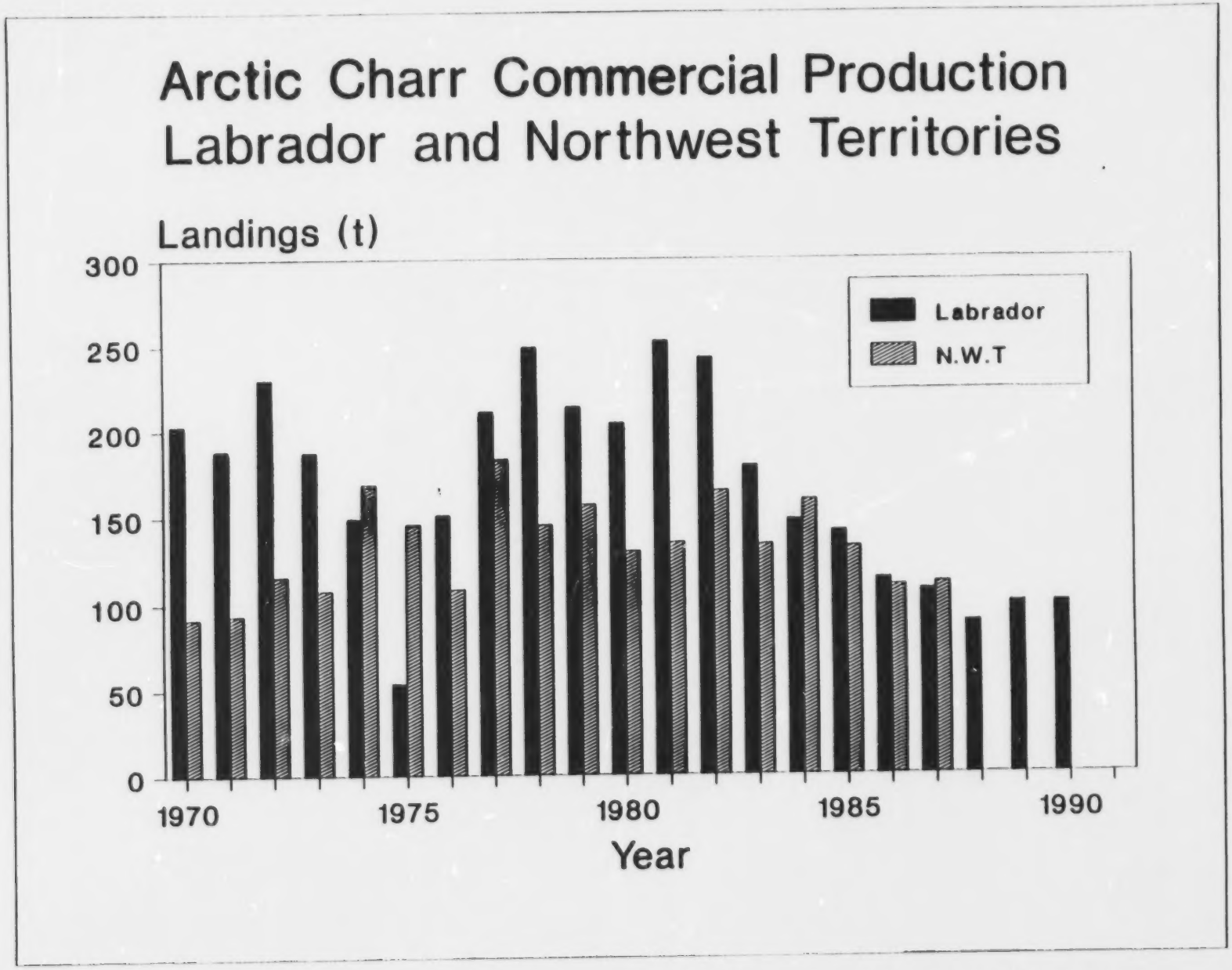


Fig. 5. Comparison of anadromous Arctic charr commercial landings from Labrador and the Northwest Territories.

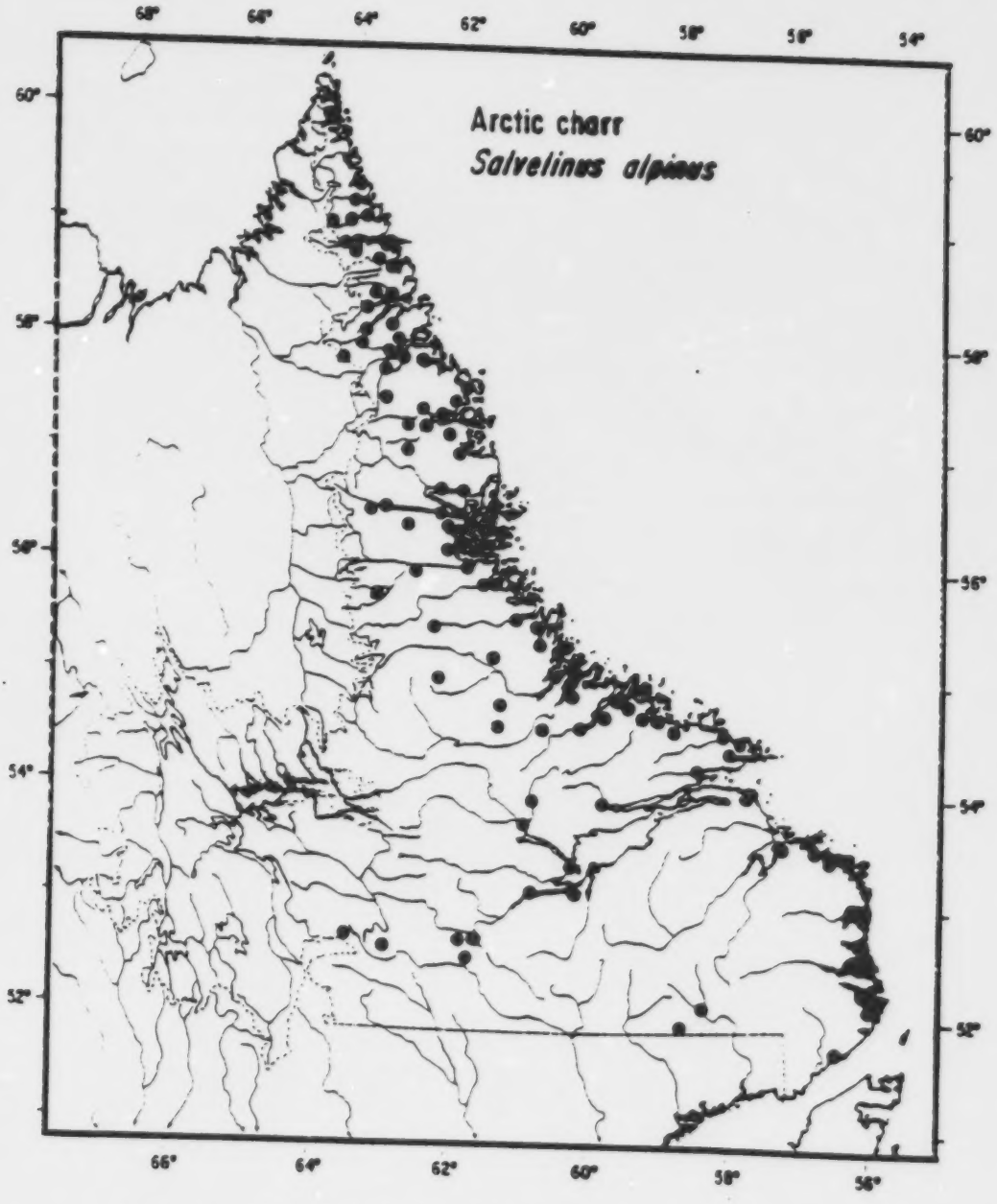


Fig. 6. Distribution of Arctic charr populations in Labrador.

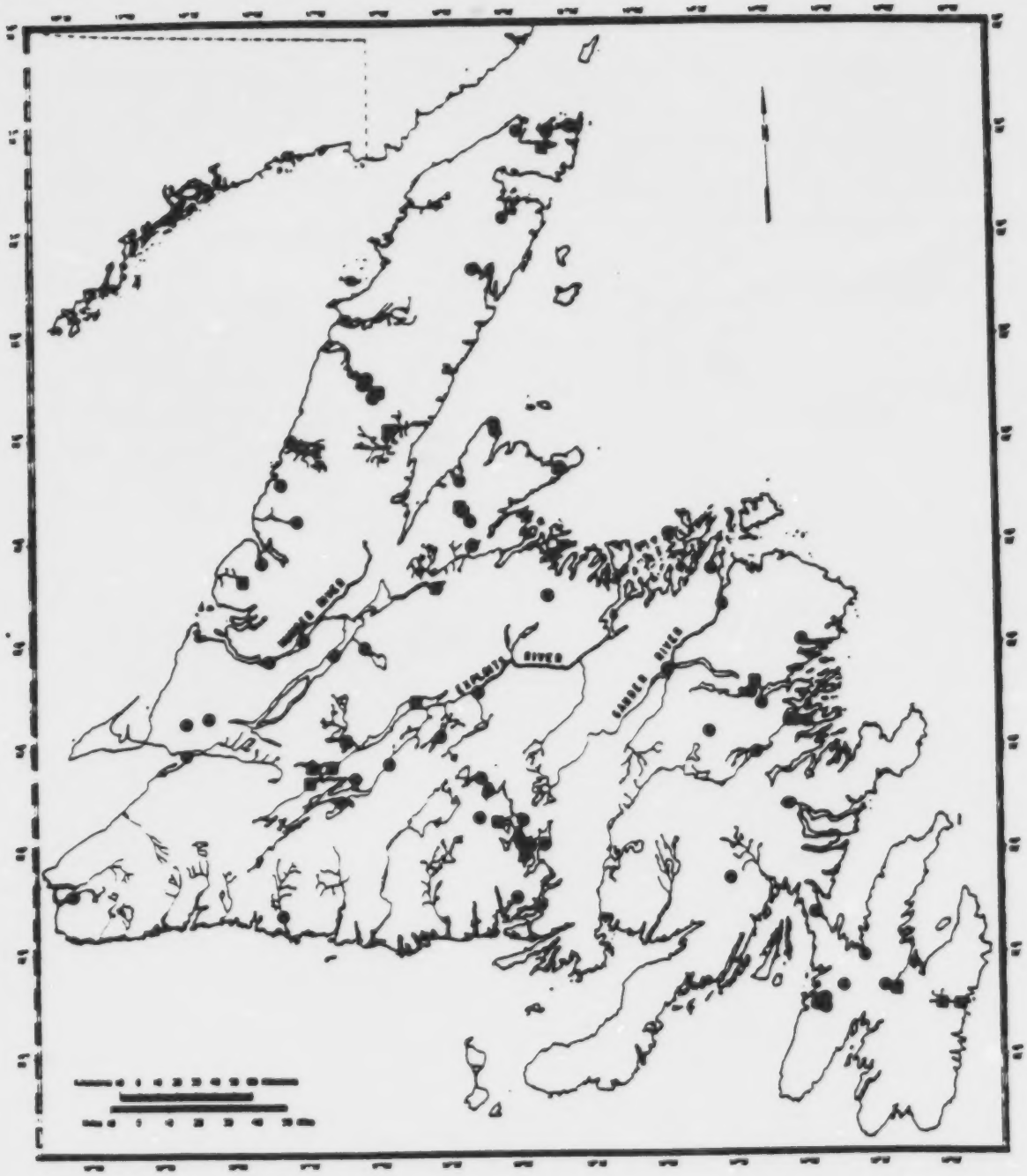


Fig. 7. Distribution of known Arctic charr populations in insular Newfoundland.

FIG. 8. Mean Length at age in various insular Nfld. Arctic Charr populations

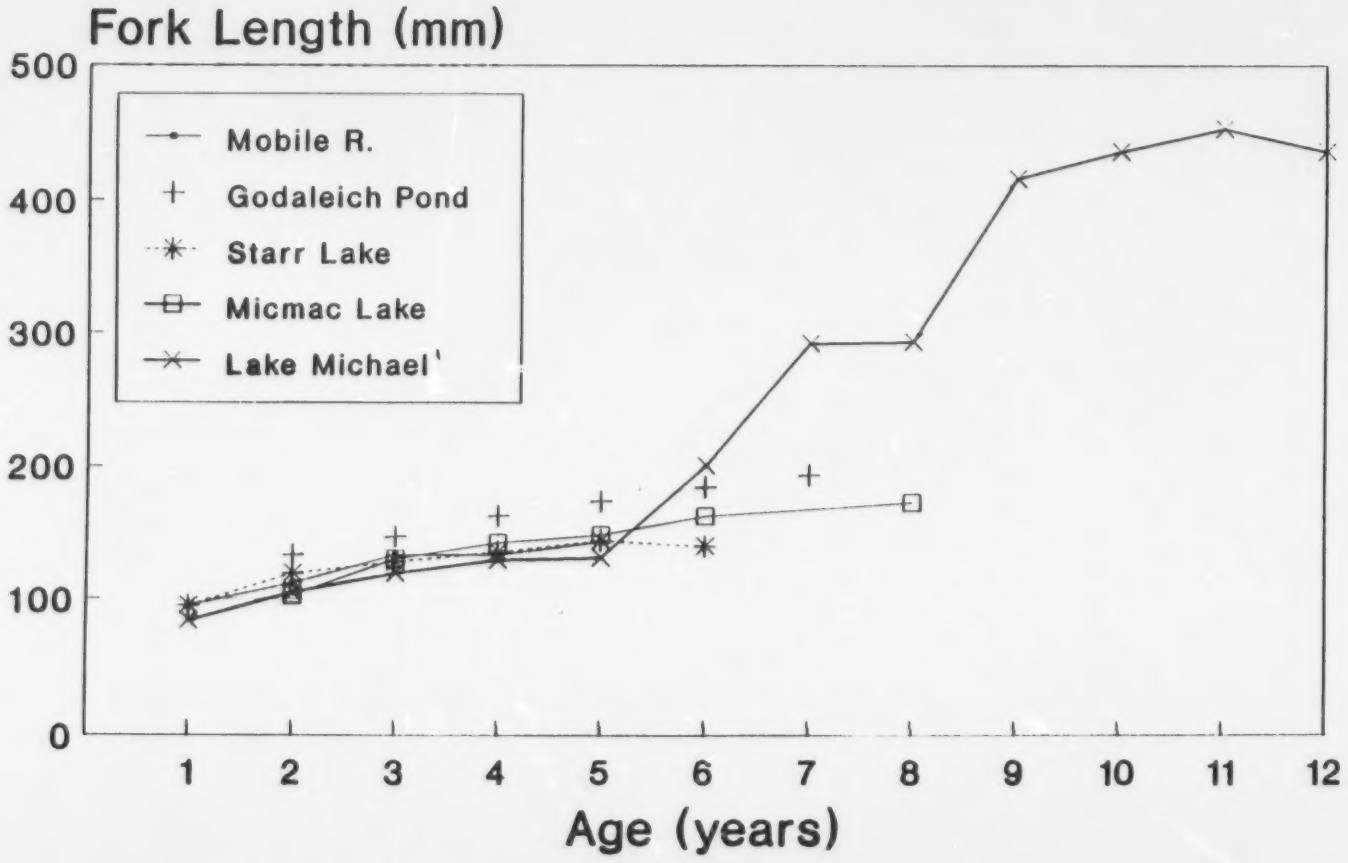
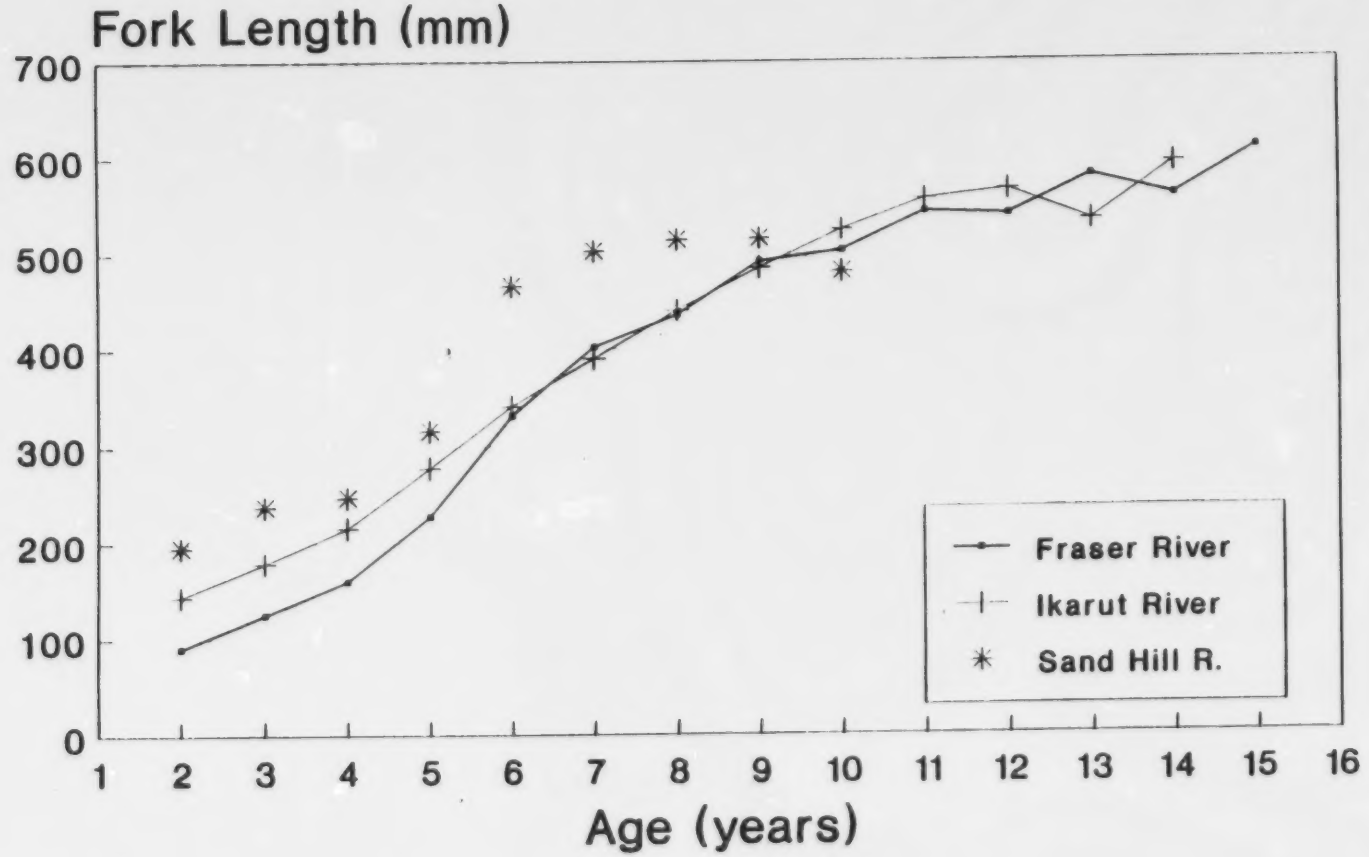


FIG. 9. Mean Length at age in various Labrador Arctic charr populations



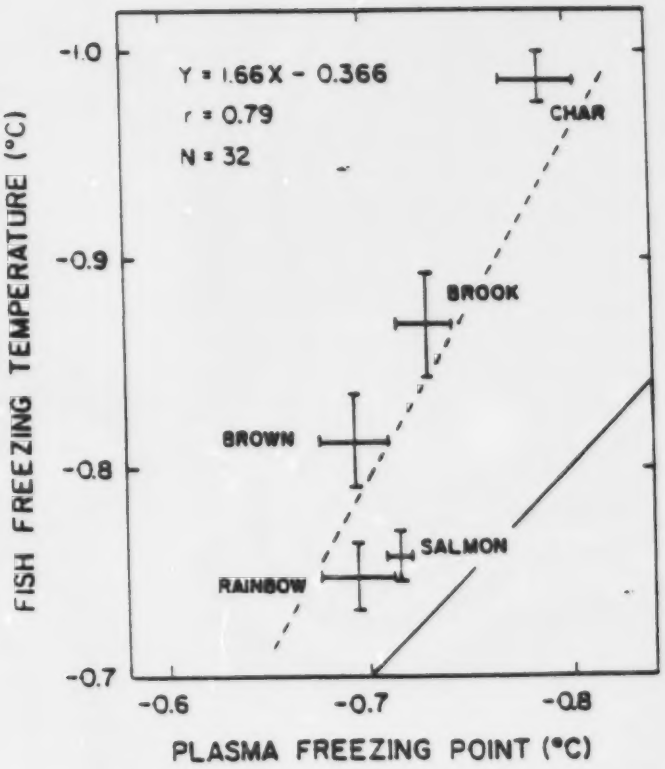


Figure 10.

Relationship between fish freezing temperature and plasma freezing temperature. All values are plotted as means ± 1 SE. The solid diagonal line represents the temperature at which the fish should die as predicted from the plasma freezing points. The broken diagonal line represents the regression relating the fish freezing temperature to the plasma freezing temperature. The regression was computed from individual values. N = Number of fish.

ARCTIC CHARR AQUACULTURE PROGRAMS AT THE DEPARTMENT OF FISHERIES AND OCEANS, FRESHWATER INSTITUTE, WINNIPEG, MANITOBA

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Rockwood Aquaculture Research Centre (RARC)

The Department of Fisheries and Oceans, Central & Arctic Region, carries out Arctic charr (Salvelinus alpinus) aquaculture research at the Rockwood Aquaculture Research Centre (RARC). At the site, which is located north of Winnipeg, there is (a) a main hatchery building and (b) a certified broodstock building. In the main building, Arctic charr, rainbow trout, brook trout, and walleye (see Table 1 for list of Arctic charr stocks) are raised. There are 20 troughs (40-150L tanks), 204 60L tanks, 34 1500L tanks, and 12 5400L tanks with both traditional and innovative culture systems used for on-site research and/or raising fish for researchers in Winnipeg. In the broodstock building, there are 4 troughs, 8 150L tanks and 12 1500L tanks which are used to raise certified Arctic charr and rainbow trout.

The facility uses well water at 6-7°C for its water source. Water temperature can be increased by solar energy or through the use of recirculation. It is possible to operate the majority of the facility on recirculation. RARC is staffed by 4 full-time staff with 3 living on-site.

The objectives of the Aquaculture Research Section in Winnipeg are:

1) To conduct research that will lead to the development of the aquaculture potential of species such as Arctic charr, walleye, and sturgeon. Research is aimed at anticipating and responding to the present and future needs of the aquaculture industry.

2) To transfer technology from that research to the aquaculture industry in the form of information, advice, eggs, and fish that are not readily available to the industry.

3) To provide a service to researchers at the Freshwater Institute (Winnipeg), universities, and governments who require fish and eggs to support their programs.

Research Programs and Staff

Current research programs are in the areas of genetics (Brigitte de March), nutrition (Jo-Anne Tabachek), physiology (Michael Giles), fish husbandry, biotechnology, growth and growth models (Michael Papst), walleye culture (Jack Mathias), and recirculation (Murray Foster and Lenore Vandenbyllaardt). Graduate students (Supattra Uraiwan, Randy Baker, Jean Tompkins, and Xiuwie Yang) and University of Manitoba professor, Terry Dick, have also done some of the research on charr. A comparison between three Arctic charr strains (Nauyuk Lake, Norway, and Labrador) on various stock characteristics, based on research at RARC, is given in Table 2. An overview of the research was presented at the workshop and a list of publications is given in Appendix 1.

Our travel to the four Atlantic provinces and our participation in this workshop support both the research and the Technology Transfer portions of our program. Consultation with those in the Arctic charr industry was aimed at the following objectives:

1) to identify and priorize the areas where research is required in order for Arctic charr culture to advance;

2) to establish and/or improve communication with people in the aquaculture industry who are associated with Arctic charr culture;

3) and to investigate the potential for collaborative research with researchers, fish producers, and feed manufacturers.

Technology Transfer Agreements

Over the past 4 years, Arctic charr eggs and/or fish have been shipped to every province and Territory in Canada (see Table 3). These have been shipped to growers, researchers, and governments. Most eggs are now shipped to clients who have Technology Transfer Agreements with The Department of Fisheries and Oceans, Central & Arctic Region. Draft copies of a generic Technology Transfer Agreement were distributed (see Appendix 3).

The client agrees to:

1) Supply DFO with growth and survival data and the intention is for DFO and the client to write a report containing this information;

2) raise the charr for broodstock;

3) support the Technology Transfer Program by providing fish feed to RARC at a current value of $0.04 per eyed egg.

The Agreements were originally for 3 years, but are now for one year and can be renewed for a total of three years as long as both the client and DFO agree on the renewal.

This is the first year that the industry has begun to produce and market charr eggs and it may be several more years before the industry is really in a position to meet the demand for charr eggs. It is the intention of these agreements for the industry to become self-sufficient. This is why one of the conditions of the agreement is that charr be raised for broodstock. Once the industry becomes self-sufficient, eggs will no longer be supplied since DFO does not want to be in competition with the industry.

Handouts List

The following handouts were distributed during the workshop and have been included in Appendices 1-3.

1) List of publications on Arctic charr culture that have resulted from research conducted at the RARC and the Freshwater Institute in Winnipeg

2) Arctic charr Culture Bulletin No. 1, June 1990

3) Draft copy of the Technology Transfer Agreement

ARCTIC CHARR STOCKS RAISED AT
ROCKWOOD AQUACULTURE RESEARCH CENTRE, MANITOBA

ORIGIN		YEAR RECEIVED AS EGGS	
NAUYUK LAKE, N.W.T.	ANADROMOUS	1978	
	LANDLOCKED	1978	
LABRADOR (FRASER R.)		1980	
		1981	
		1984	(CERTIFIED)
NORWAY		1980	
TREE RIVER, N.W.T.		1988	(CERTIFIED)

Comparison of Three Stocks of Arctic Charr, Raised at Rockwood Aquaculture Research Centre, Manitoba

	NAUYUK	NORWAY	LABRADOR
Appearance		Slim, dark + most muscular	
Optimum Temp.	10-13C	13C	13C
Growth Rate	Slower than Lab at 10C	Slower than Lab at 10C and 13C	Faster growth
Spawning:			
Age at first spawn	(4)-5-6	(3)-4	(3)-4
Time	Aug. 21-early Sept.	Sept. 21-Oct 31	Late Sept.-early Jan.
Duration	3-4 wk	5-6 wk	4-5 months
Egg Size	4-5 mm	3 mm	4-5 mm
No. Eggs	1200-2500 (up to 5000)	3000	3000-4000 (up to 10-13,000)
Survival:			
Eyed	75-85	75-80	35-75 (i.e. variable)
Swim up	good	good	variable
First-Feeding	good	poor (some improvement at 10C)	good (improved survival at 10C)
Tolerance to low D.O.	most tolerant	tolerant	tolerant
Affinity of Hemoglobin for Oxygen	high	low	low

ARCTIC CHARR EGGS SHIPPED
FROM ROCKWOOD AQUACULTURE RESEARCH CENTRE

YEAR	NO.	PROVINCE	CERTIFIED	UNCERTIFIED
1987/88	1	YK	6,900	12,100
	4	BC	25,000	
	1	ALTA	2,200	
	6	SK	32,950	
	1	NS	1,600	
	1	PEI	1,600	
	2	NFLD	10,000	
			80,250	12,100
1988/89	1	YK	30,000	
	5	BC	22,500	
	4	SK	22,800	
	2	ONT	8,000	
	2	PQ	6,000	
	2	NB	10,500	
	3	NS	17,000	
	3	NFLD	9,000	
			125,800	0
1989/90	1	YK	28,670	
	1	BC	10,000	
	2	SK	20,140	
	1	MAN		12,000
	2	ONT	18,500	28,090
	1	PQ	9,000	
	1	NB	6,000	
	1	PEI	3,000	
			95,310	40,090
1990/91	2	ONT	18,500	62,240
	1	BC	25,000	
	2	SK	39,000	6,850
	1	ALTA	9,700	
	1	NFLD	8,400	
	1	PQ	10,900	
	2	MAN	10,000	7,500
			121,500	76,590

TOTALS (1987-1991) 422,860 + 128,780 = 551,640

NOTE: ARCTIC CHARR WERE ALSO SUPPLIED AS LIVE FISH TO POLAR SEA FISHERIES (YK), ARCTIC FISH COMPANY (SK), ELDERS AQUAFARMS (NOW CALLED AG-PRO FISH FARM, MAN.), WILDWOOD TROUT HATCHERY (MAN), ARCTIC AQUAFARMS (MAN), OAK HAMMOCK FISH FARM (MAN).

COMPARISON OF THE GROWTH PERFORMANCE OF RAINBOW TROUT (Oncorhynchus mykiss) and ARCTIC CHARR (Salvelinus alpinus)

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Overview

Arctic charr were better suited than rainbow trout to culture at high densities. The growth rate of Arctic charr increased with density from 10 kg/m^3 (0.62 lb/ft^3) to a plateau at 40-60 kg/m^3 (2.5-3.75 lb/ft^3) and then decreased. The growth rate of rainbow trout declined linearly from densities of 10-85 kg/m^3 (0.62-5.3 lb/ft^3) and was lower than charr at 85 kg/m^3 (5.3 lb/ft^3).

The optimum temperature for Nauyuk Lake charr was 10-13°C, closer to 13°C for Labrador and Norway charr and 13-16 to 16-17°C for two strains of rainbow trout. Arctic charr had equivalent to higher growth rates than rainbow trout at 7-10°C, while rainbow trout had higher growth rates than charr at 13-19°C. At 19°C, the growth rate of Norway and Nauyuk Lake charr declined by over 50% while it declined only 25% for the Labrador charr.

At 13°C and initial densities of 10-15 kg/m^3 (0.62-0.93 lb/ft^3), Labrador Arctic charr could be raised from 10g to 200g in 25 wk while trout required 19 wk. A wide variation in growth rates between charr has been observed, even within a single family raised under the same conditions. A large part of this was under genetic control, with the occurrence of some dwarf and precocious fish as well as fast growing individuals. The harvest of charr can be spread over a long period of time, harvesting them earlier and later than rainbow trout, but a portion of the population may never reach harvestable size.

Arctic charr fingerlings (4.6g) require diets containing 54% crude protein with 20% total lipid for maximum growth at 12°C, but 44% protein with 20% lipid for a lower feed cost/kg gain. Diets containing 34% protein and/or 10% lipid resulted in very poor growth. Arctic charr require diets with higher protein and lipid than the requirements reported for rainbow trout (35% protein at 15-20% lipid to 40% protein at 10% lipid).

Arctic charr were first investigated because it was expected that they would have a low optimum temperature and grow well at the cold water temperatures present on the prairies and in northern Canada (Baker 1983). It was also expected that charr could be an

alternate species to rainbow trout and could provide producers with a different niche in the marketplace. In December, 1990, the price for whole dressed pan-size Arctic charr was $12.78 per kg ($5.75 per lb) and $5.00 - $6.22 per kg ($2.25 - $2.80 per lb) in Canadian dollars for rainbow trout (Talley 1991). However, the decision to raise Arctic charr should not be based solely on market price because, as more product enters the marketplace, there is the possibility that the price will decline.

Arctic charr have been raised at the Rockwood Aquaculture Research Center (RARC) in Manitoba since 1978. Stocks have been obtained from the Nauyuk Lake in the Northwest Territories, the Fraser River in Labrador, and from the Sunndalsora Hatchery (eggs collected at Storvatn) in Norway. Stocks of rainbow trout described in this paper originated at Mount Lassen Trout Farm, California, and the Sunndalsora Hatchery in Norway. This paper is a review of the research conducted by many researchers with these stocks at RARC in the areas of nutritional and environmental requirements.

Dietary Effects on Growth

In two consecutive experiments, Sunndalsora rainbow trout and Norway Arctic charr (Experiment 1) and Labrador Arctic charr (Experiment 2) were fed a commercial rainbow trout diet and a control diet for 84 days at 12°C (Table 1)(Tabachek 1984, Tabachek, unpublished data). Sunndalsora rainbow trout gained significantly more than Norway Arctic charr when fed either diet. Norway charr gained significantly less when fed the commercial trout diet compared to the control diet. When these same lots of feed were fed to Labrador charr under the same conditions, there were no differences between diets and Labrador charr grew as well as or better than trout in the previous experiment and had similar feed conversions and feed efficiencies. Feed conversion and efficiency were significantly poorer for the Norway charr as compared to the Labrador charr and were particularly poor for Norway charr fed the commercial diet.

The control diet was reformulated to obtain diets with 34, 44, and 54% protein at each lipid level - 10, 15, and 20% (Tabachek 1986). At 12°C, Nauyuk Lake Arctic charr fingerlings gained the most when fed diets containing 54% crude protein with 20% total lipid and gained significantly more than those fed a diet containing 44% protein with 15% lipid. In general, increasing the dietary protein from 34% to 44% resulted in a 20% increase in weight gain while increasing the protein from 44% to 54% resulted in an 11% increase in weight gain. Increasing the dietary lipid from 10% to 15% resulted in an 18% increase in weight gain while increasing the lipid from 15% to 20% resulted in a 5% increase in weight gain. Takeuchi et al. (1978) reported that 2.3g rainbow trout raised at 15-18°C required 35% protein at 15-20% lipid for maximum growth and Satia (1974) reported that 3.5g rainbow trout required 40% protein at 10% lipid at 16-27°C. Although no

comparative experiments were conducted at RARC with rainbow trout, it is expected that these levels of protein and lipid would have resulted in poor growth for the Nauyuk Lake Arctic charr.

Temperature Effects on Growth

Uraiwan (1982) compared the growth rates of Nauyuk Lake, N.W.T. Arctic charr, Gods River, Manitoba brook trout (Salvelinus fontinalis) and Sunndalsora rainbow trout at 10, 13, 16, and 19°C (Table 2). At 10°C, Nauyak Lake Arctic charr had a higher specific growth rate than rainbow trout or brook trout while rainbow trout had higher growth rates than Arctic charr at 13, 16, and 19°C. Baker (1983) compared the growth rates of Labrador and Norway Arctic charr and Mt. Lassen rainbow trout at 7, 10, 14, and 19°C (Table 2). The growth rates of trout and Labrador charr were equivalent at 7 and 10°C while trout had a higher growth rate than either stock of charr at 14 and 19°C. At 19°C, the growth rate of Nauyuk Lake and Norway charr declined by more than 50% of the growth rate at 13-14°C while that of the Labrador charr declined by only 25%. The optimum temperature for growth was 10-13°C for Nauyuk Lake charr, closer to 13°C for Labrador and Norway charr, 13-16°C for Sunndalsora rainbow trout and brook trout and 16-17°C for Mt. Lassen rainbow trout.

Density Effects on Growth

Arctic charr and rainbow trout responded differently to density. In comparing the growth rates of Labrador Arctic charr and Mt. Lassen rainbow trout at densities of 10 to 85 kg/m^3 (0.62 to 5.3 lb/ft^3), the growth rate of Arctic charr increased with density to a plateau at 40 to 60 kg/m^3 (2.5 to 3.75 lb/ft^3) and then decreased (Baker and Ayles 1990). In contrast, the growth rate of rainbow trout declined linearly from densities of 10 to 85 kg/m^3 (0.62 to 5.3 lb/ft^3). That is, Arctic charr grew poorly at low densities and were well suited to intensive production. In Canada and Norway, Arctic charr have been raised at densities of 80 to 150 kg/m^3 (5.0 to 9.4 lb/ft^3)(Papst and Hopky 1989, Robbins et al. 1990). While the optimum density is 40-60 kg/m^3 (2.5 to 3.75 lb/ft^3), the optimum conditions for growth must still be provided to achieve satisfactory growth. This was shown when Tabachek (unpublished data)(Figure 1) investigated the effect of flow rate on the growth of charr at different densities. Under conditions of lowest flow rate (1 l/min in a 60 l tank), Nauyuk Lake charr (initial weight= 26g) raised at 60 kg/m^3 (3.75 lb/ft^3) at 10°C were able to tolerate conditions in which the dissolved oxygen was 1.3-3.0 ppm (mean= 2.1) at the end of the feeding day and only 0.5 ppm higher at the beginning of the feeding day. Although the specific growth rate of this group was poor (0.35% BW/d) compared to 1.1% BW/d for the groups receiving flow rates of 2.5 and 3.5 l/min, mortality was only 4% during a 6 wk period. This result contrasts with that of Penney (pers. commun.) who found larger charr (500-1500g) of the Labrador strain experienced heavy mortalities at

about 5.5 ppm of dissolved oxygen. It is expected that the mortality of rainbow trout would also have been much higher under these conditions.

Size Variation during Growth

It is estimated that 19 wk would be required for rainbow trout and 25 wk for Labrador Arctic charr to grow from 10 g to 200 g at 13°C (calculated from Papst and Hopky 1989). A wide variation in growth rates of individuals within a population of charr has been observed. Papst and Hopky (1984, 1989) selected initial populations for a weight of 5-16 g for Arctic charr and 9-23 g for rainbow trout. At the end of the trial period, charr exhibited weights of 25-408 g (mean= 183 g) while trout had weights of 80-330 g (mean= 187 g). That is, there were both fast growing and slow growing individuals in the charr population. This wide variation in growth has been observed among siblings raised under the same conditions. A large part of this variation has been found to be under genetic control with some families exhibiting much less variation than others (Tompkins 1989, de March 1991, Papst unpublished data). While Papst found that dwarfs and precocious fish were evident in the small portion of the population (Papst unpublished data), de March (pers. commun.) has not seen evidence of precocious charr in Canadian stocks. Papst and Hopky (1984) graded a population into three size classes and raised the size classes independently. This did not significantly improve the growth rate of the small fish and showed that there was a portion of the population that would never reach harvestable weight. This wide variation in growth has the advantage of allowing the producer to harvest charr over a long period of time and spread out the production time of harvestable fish by harvesting them earlier and later than rainbow trout. However, it has the disadvantages of requiring additional grading and of having a portion of the population never reaching harvestable size (Papst and Hopky 1989).

Scope for Future Research

It should be noted that in all the growth trials referred to in this paper, the researchers used rainbow trout diets containing 45% protein and 15% lipid and low initial densities of approximately 10 kg/m^3 (0.62 lb/ft^3). Under more ideal conditions for Arctic charr, growth rates of the charr could be expected to increase. Over the past century, domesticated stocks of rainbow trout have been developed and the culture techniques and diets have been perfected. In contrast, Arctic charr have only been cultured for 12 years and the third generation hatchery stock is now being raised. There is much to be learned raising Arctic charr. Future research should address such nutritional areas as the pigmentation of charr and nutritional requirements of all life stages and under different environmental conditions. There are many ways in which the three Arctic charr stocks mentioned above differ from each other. Research should address evaluation of other stocks under

different environmental conditions to select stocks that are suited to different habitats. Research is required in genetic selection to select for desirable traits and overcome or manage the variation in growth rates. Increasing the survival of eggs and early rearing techniques are also important areas for future research.

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Table 1. Specific growth rates (% body weight/day) for Arctic charr, brook trout and rainbow trout during 6 week experiments at maximum ration at several temperatures.

	Temperature (C)					
	7	10	13	14	16	19
From graph of Uraiwan (1982) (initial weight 8-9g):						
Rainbow trout (Sunndalsora, Norway)	-	2.0	2.1	-	2.1	1.9
Arctic charr (Nauyuk Lake, NWT)	-	1.8	2.0	-	1.85	0.9
Brook trout (Gods River, Manitoba)	-	1.6	1.9	-	1.9	1.1
From Baker (1984) (initial weight 10g):						
Rainbow trout (Mt. Lassen, CA)	0.79	1.75	-	2.70	-	2.55
Arctic charr (Fraser R, Labrador)	0.80	1.77	-	2.07	-	1.48
Arctic charr (Sunndalsora, Norway)	0.81	1.24	-	1.85	-	0.87

Table 2. Performance of rainbow trout and Arctic charr fed the same feeds in two consecutive experiments for 84 days at 12°C.

	Initial weight (g)	Weight gain (g)	Feed conv[1]	Feed eff[2] (%)
EXPERIMENT 1:				
Sunndalsora rainbow trout				
Control	13.0	51.2[a]	1.10[a]	91.0[a]
Commercial	13.1	55.2[a]	1.25[a]	80.1[a]
Norway Arctic charr				
Control	12.9	31.3[b]	1.45[b]	69.0[b]
Commercial	13.0	19.9[c]	2.73[c]	40.4[c]
EXPERIMENT 2:				
Labrador Arctic charr				
Control	12.3	59.9	1.15	87.0
Commercial	12.3	52.8	1.17	85.5

[1] Feed conversion = dry weight feed / wet weight gain
[2] Feed efficiency = (wet weight gain / dry weight feed) x 100

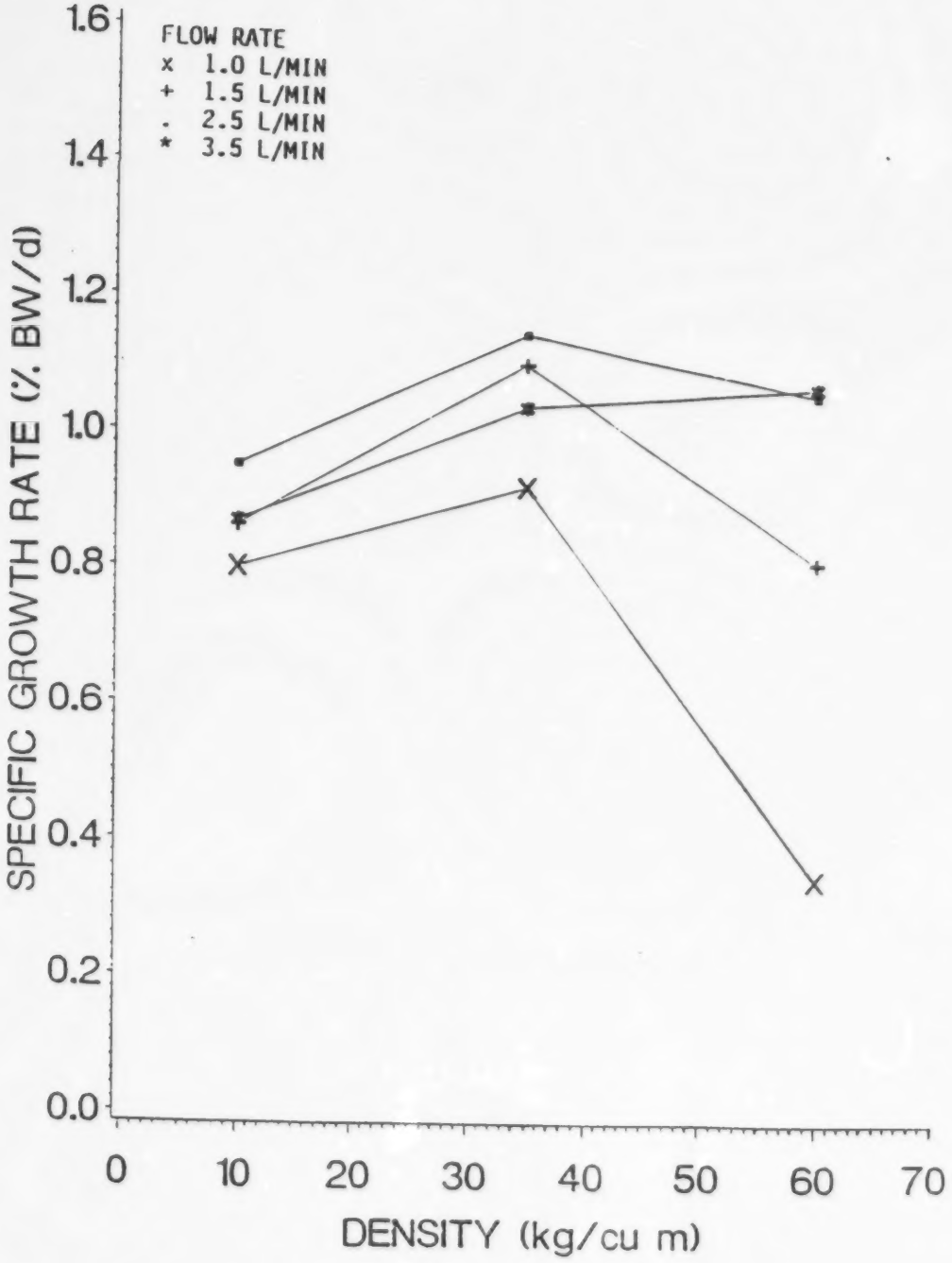

Figure 1. Specific growth rate of Nauyuk Lake, NWT Arctic charr (initial weight = 26 g) at 10°C when raised at different densities and flow rates.

GENETIC STUDIES WITH ARCTIC CHARR AT THE ROCKWOOD AQUACULTURE RESEARCH CENTRE WINNIPEG, MANITOBA

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The Aquaculture Genetics Project at the Rockwood Aquaculture Research Centre (RARC) at Gunton, Manitoba, is examining aspects of the genetics of Arctic charr which might be important in improving strains or stocks for aquaculture. Strains of Arctic charr from 1) Nauyuk Lake (Kent Peninsula, NWT), 2) the Fraser River in Labrador, and 3) Storvatn in northern Norway, are being examined. The Labrador strain, started with 29 field-collected parents in 1980, now constitutes the third generation of pedigreed stock, and is used for most studies. It's culture history is outlined in de March and Baker (1990).

It has been determined that growth and "condition", a measure of plumpness, have a genetic base in Arctic charr (de March 1991a). That is, some parents consistently produce larger or plumper offspring than others. This suggests that the Labrador charr can be improved as an aquaculture species by selecting fish with desired properties for future generations. Studies of the third pedigreed generation are now in progress.

It was also determined that parents that produce larger offspring, measured as an average weight or length in a family, also produce offspring with less size variation than parents that produce smaller offspring. That is, the coefficient of variation (CV= standard deviation/mean) was smaller in families with a large mean weight. The smallest fish in families with a high mean weight were still larger than the smallest fish in families with a low mean weight. It is therefore believed that selection for large size might also reduce the size variation in charr.

The size variability of Arctic charr, both in the field and in culture, has been the object of several research projects at the Rockwood Aquaculture Research Centre. The author believes that the size variability is primarily a genetic phenomenon, although there is no doubt that environmental or maternal factors will increase or possibly decrease the variability.

The possibility of obtaining improved production through the use of F1 (first generation) hybrids was examined. Often, with domesticated plants and animals, F1 hybrids are faster growing, larger, and less variable in size than their parents. Sometimes

they demonstrate desireable characteristics from both strains. In my experiments, hybrids of Nauyuk Lake and Norwegian charr were examined and compared to the parental strains (de March 1991b). The Nauyuk female x Norwegian male hybrids were, on the average, slightly larger and faster growing than the pure Nauyuk fish, which were larger than pure Norwegian fish. The Norwegian female x Nauyuk male hybrids were, on the average, considerably smaller than either pure strain. However, both types of hybrids had more size variation than the parents. The largest and the smallest fish in the entire experiment were hybrids. It was believed that the typical response of hybrid vigour and reduced variability did not occur because the two strains were not inbred, as is the case with agricultural species.

To determine whether or not offspring characteristics relate to the parents, genetic studies require that each male and female fish be crossed with several mates. Such experimental designs demonstrated that egg hatching success and fry survivorship were determined entirely by the female, and never by the male. That is, eggs from the same female in the same year had the same hatching success regardless of the male parent, while eggs from different females fertilized by the same male did not have the same hatching success. No relationship between egg survivorship and the size of the offspring produced could be detected. However, a weak relationship between egg size and size variability and the early sizes of juveniles existed. In both cited experiments, family size characteristics and size variability were more strongly related to the female than to the male. However, the female effect decreased with time, probably as offspring expressed their true genetic potential rather than the egg quality of the female.

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NEW TECH CHAR FARMS LTD

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New Tech Char Farms Ltd, a privately owned local company, has established a small-scale hatchery for raising Arctic charr at Port Rexton. Fish were first brought into the hatchery in 1989 from the Rockwood Hatchery in Manitoba. Disease-free certification, under the Canadian Fish Health Protection Regulations, was granted in 1990. Fish are now being grown at the site to develop a broodstock.

We have had our share of startup problems, including lack of adequate capital, lack of sufficient eggs for stocking, etc. Due to equipment, time, and financial restraints, the operation encountered problems that would not normally arise with a better equipped facility. However, encountering problems has also led to site specific solutions. As a result, New Tech Char Farms has determined specific equipment needs and facility design to allow near maximum production at this site, while providing several safeguards to maintain fish survival.

New Tech Char Farms hopes to develop a much larger facility based on high ratio water recirculation using principles of settlement, water clarification, and biological filtration to remove waste products from the culture water. The design will be a simple one without reliance on high technology equipment that is hard to repair, expensive to maintain, and prone to breakdown.

New Tech Char Farms realizes that, although research carried out to date has provided much needed information and represents a very real effort aimed at evaluating Arctic charr culture in Newfoundland, much more effort is required to research and develop Arctic charr as a commercial species. It is essential that the province as a whole make a concerted effort at a comprehensive Arctic charr egg take this year. This will see the beginning of real "applied and laboratory" research into broodstock selection by practical stock performance assessments. In addition, fish farmers in Newfoundland, as well as in other provinces, have found the limited supply of starting stock to be a major impediment to research and commercial development.

ARCTIC CHARR AQUACULTURE PROJECTS IN THE BONAVISTA PENINSULA AREA

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The economy of the Bonavista Peninsula and surrounding areas has traditionally been based on renewable natural resources. For centuries, the fishery has been the mainstay of many communities. More recently, the natural environment, cultural heritage, and growing entrepreneurial spirit have provided the impetus for a thriving tourism industry.

The viability of existing fisheries in Newfoundland has come under attack in recent years with quota reductions, low and uncertain catches, and related problems. Rural economies relying on these fisheries are in a state of decline. Development of new opportunities and diversification of rural economies could be the key to reversing this trend.

The Bonavista-English Harbour Development Association (BEHDA) believes that the development of an aquaculture industry in the area is a step towards diversifying the rural economy and providing an alternate source of employment in an area of high unemployment. We feel a cottage industry could be developed to produce full or supplementary income for the rural family. Further, we believe that charr culture could and should be developed as a cottage industry.

To achieve this goal, six local development associations, business groups, and commercial enterprises in the Bonavista - Terra Nova area have joined forces to form a Regional Aquaculture Development Foundation. The goal of the Foundation is to promote and develop aquaculture activities in the area in an orderly manner. In 1990, a conceptual plan of action was developed, which would include the following:

- construction of a research and development facility, including an experimental hatchery, to carry out applied research and development,

- a research program to develop improved strains of fish for commercial production, and for assisting development of commercial enterprises,

- construction of one or more commercial growout facilities for training purposes, technology transfer to local farmers, and to offset the costs of operating the facility, and

- construction of commercial fishout ponds, to operate in conjunction with the research facility.

Work on Phase 1 of this plan, locating a site for a facility for raising char, has already begun.

VALLEY CHAR INC.

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Valley Char Inc. is a Deer Lake-based company established to develop a commercial Arctic charr operation at Main Dam in Grand Lake. We have been active since 1985 collecting data at the site pertaining to water temperature, depths, dissolved oxygen, and overall composition.

Valley Char Inc. has begun a pilot scale development project at Main Dam in Grand Lake. The project aims to assess the suitability of the site for growout of Arctic charr in lake cages. It involves placing charr fingerlings in cages at Main Dam and evaluating their performance (ie. growth, mortalities, etc.) for one year. The site at Main Dam will be assessed as a potential culture site and various physical parameters at the site (temperatures, water currents, dissolved oxygen, anchorage, etc.) will be recorded. Some concern has been raised about the environmental impact of the operation at the Main Dam site on the watershed as a whole and, more specifically, on the municipal water supply to Deer Lake. Hopefully, the data collected during the pilot phase will lay to rest many of these concerns, allowing Valley Char to proceed with commercial scale development of the site. In the long term, Valley Char hopes to develop a hatchery and commercial scale fish farm in the area.

AQUAMETRICA LTD

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Aquametrica is a small, locally owned company specializing in the development of ventures in aquaculture and fisheries. The company has had considerable experience in commercial aquaculture in Ontario and has been instrumental in investigating the commercial potential for new or underutilized species for aquaculture and the capture fisheries.

Aquametrica is planning to construct and operate a groundwater based hatchery near Indian River, Springdale. This facility will be used to develop and propagate disease-free, genetically superior stocks of Arctic charr for commercial aquaculture in Newfoundland. The Hatchery will make extensive use of ground water for its water requirements.

WORKSHOP WRAP-UP

The following is a synopsis of key points or conclusions which were expressed during the workshop presentations or subsequent discussions which might be of interest to existing or prospective fish farmers.

Arctic charr as a culture species

Growth and variation in growth rate

- Arctic charr grow better at higher densities around 60 kg/m^3 than do rainbow trout and have less variation in size at the higher densities. Charr have been cultured commercially at densities approaching 100 kg/m^3.

- The wide size variation was observed between members of a single family raised under the same conditions. The size variation is believed to be largely due to genetic factors. Under commercial conditions, some of the population may never reach commercial size.

- The temperature optimum for Arctic charr is about 10-13°C compared to 13-17°C for rainbow trout. Arctic charr growth rates decline significantly at temperatures approaching 19°C.

- Arctic charr require diets higher in protein and lipid than for rainbow trout to promote optimum growth.

- Brood fish which produce larger offspring also produce offspring with less size variation than parents that produce smaller offspring. Therefore, selection for large size might also reduce the size variation in charr. Family size characteristics and size variability were more strongly related to the female parent than to the male.

- In hybridization experiments with Nauyuk Lake and Norwegian strain charr, the hybrid offspring had greater size variation and were smaller, on average, than either of the parental strains.

Fish behaviour

- At higher culture densities, charr are less agonistic, and spend more time shoaling. These changes in fish behaviour, due to a breakdown of aggression-dominance hierarchies, allow the fish to divert more energy to growth rather than swimming and various agonistic interactions resulting in a higher growth rate and lower size variation.

Disease problems

- In contrast to ouananiche, the landlocked form of Atlantic salmon, Arctic charr (at least the Labrador strain) has not developed a natural resistance to PKD (proliferative kidney disease) and infected fish have been shown to experience high mortality from PKD when water temperatures exceed 12°C.

- As water temperatures exceeded 15°C, at Bay D'Espoir charr yearlings experienced a series of outbreaks of furunculosis and septicemic bacterial infections resulting in very high mortality although comparable sized rainbow trout in adjacent tanks were not affected.

Marine culture

- In sea pen culture, Arctic charr experienced no problems with buoyancy due to swim bladder inflation and lack of access to surface air under ice cover conditions compared to salmon but exhibited growth rates throughout the summer that were inferior to both salmon or trout.

- During summer temperature stratification, sea pen cultured charr tended to concentrate around 13.4°C in the thermocline and would not come through the overlaying warmer surface waters to feed.

- Pan-sized charr at Bay D'Espoir Hatchery had a large variation in size and condition factor compared to rainbow trout. These same problems were also evident in yearling charr at NAFC. Both growth and condition are believed to be genetically based.

Other physiological factors

- The hue and intensity of flesh coloration of pan-sized charr at Bay D'Espoir was inferior to that of trout fed the same commercial diet.

- Market size charr >500g required 9 weeks of feeding on pigmented diets to gain adequate flesh coloration.

- Pigment from the diet appears to be absorbed in the skin prior to deposition in the flesh.

- Arctic charr apparently can tolerate oxygen levels much lower than rainbow trout or salmon. Nauyuk Lake strain fish have tolerated levels as low as 1.3 ppm.

- The Bay D'Espoir Salmon Hatchery experienced higher

mortalities with charr than either rainbow trout or Atlantic salmon at all stages of early development, particularly at hatching or later development of pinheads. Survival to the 4g size was 28%, 70%, and 75% for charr, salmon, and trout respectively. The smaller egg size of the charr and/or their apparent greater sensitivity to light at first feeding may have been contributing factors. During the first year, charr growth at 14°C was intermediate between that of salmon and trout at 18.5°C.

- Arctic charr eggs collected in the middle of the spawning season had higher biochemical nutrient composition which was correlated with greater growth and survival of resulting fry compared to that from eggs collected either early or late in the spawning season. The energy level or amino acid content of eggs may be used as a condition index for the future development, growth, and survival of embryos and alevins.

Spawning and broodstock selection

- In Winnipeg, a natural photoperiod and low temperatures around 7-9°C are used for broodstock.

- If fish are culled on the basis of size after the onset of maturation (2 years old), there is a danger of ending up with a stock of mostly one sex.

- Some charr may be alternate year spawners ie. they skip a year between spawnings. Females that do not spawn may look very "skinny". If culled out as inferior fish, you may be destroying your broodstock for next year. Tagging brood fish and accurate record keeping can help avoid this problem.

- Determining sex visually is impossible until the fish reach 3 years of age. At this time the males develop a strongly hooked jaw and are more slender and strongly coloured on the bellies than the females.

- The ripeness of the brood fish should be checked frequently (once a week) as spawning date approaches. Overripe eggs have much reduced survival.

- Within one week of spawning, brood fish are taken off their feed since faeces accidentally expelled into the spawning pan will greatly reduce fertilization success.

- During spawning, if eggs are being kept for future broodstock, the eggs from one female should be fertilized with milt from one male only to preserve the genetic

- After spawning, a few eggs are usually left in the female. If these are not removed shortly thereafter, they may form a plug and make it very difficult to release the eggs from the same female in the following year.

Comparison between strains

- Labrador charr have higher growth rates at 10-13°C than either Norway or Nauyuk charr.

- Nauyuk charr broodstock first mature in hatcheries at age 5-6 years (sometimes at age 4) while both Norway and Labrador charr spawn at age 4 (sometimes at age 3).

- Nauyuk charr spawn earlier in the season (August-September) and over a shorter period of time (3-4 wk) than either Norway (late September through October, 5-6 wk) or Labrador (late September through January, 4-5 months).

- Nauyuk charr have lower number of eggs/female (1200-2500) than either Norway (3000) or Labrador charr (3000-4000) although Norway charr eggs are smaller (3 mm) than either Nauyuk or Labrador (4-5 mm) charr eggs.

- Egg survival from fertilization to eyed stage has been lower and more variable for Labrador (35-75%) charr than either Nauyuk or Norway (75% +) charr. Survival through the first feeding stage has been good for both Labrador and Nauyuk charr but poor for Norway charr.

- Nauyuk charr have a greater tolerance to low oxygen levels than either Norway or Labrador charr.

Other aspects of interest to industry

- A commercial fishery for Arctic charr has existed in northern Labrador for many years although landings have been dropping in recent years due, at least partially, to reduction in fishing effort.

- Wild charr populations exist throughout deep lakes on the island and rivers in the Labrador portions of the province which could potentially be used as sources of alternate broodstock.

- Charr stocks on the island are characterized by small size (< 20 cm) and young age at maturity (3 years), and lower mean number of eggs per female compared to stocks in Labrador, although small stocks of large, anadromous charr also exist on the island.

- The lethal freezing temperature of charr is lower than brook trout, brown trout, rainbow trout, or salmon.

- The Freshwater Institute and Rockwood Aquaculture Center in Manitoba have been researching various aspects of charr biology, growth, nutrition, physiology, and genetics since 1978. In recent years, Technology Transfer Agreements with industry have led to transfers of eggs for broodstock development throughout Canada.

- The current market price for pan-sized Arctic charr is at least double that of rainbow trout.

- Four facilities are now currently working with Arctic charr in Newfoundland: New Tech Char Farm Ltd in Port Rexton (certified disease-free hatchery); Valley Char Inc in Deer Lake (freshwater cage operation); Great Northern Peninsula Development Association (pilot scale hatchery at Daniel's Harbour); and Bay D'Espoir Salmon Growers Cooperative in St. Alban's (hatchery and sea pen operation).

ACKNOWLEDGEMENTS

The success of any workshop depends on participation. By this criterion, this workshop can be judged very successful. The presentations given were of high quality and participants, both presenters and attendees, were forthcoming with open discussion of relevant issues. I wish to thank all those who gave their time and energy to prepare presentations and/or attend the workshop. I am especially grateful to the Industry Development Division for provision of funding assistance by the Atlantic Fisheries Adjustment Program (Development Component), without whose support this workshop would not have been possible. The AFAP (Science Component) assisted with travel costs incurred by researchers from Winnipeg.

APPENDIX 1

Publications on Arctic charr culture by the Aquaculture Research Section, Department of Fisheries and Oceans, Central & Arctic Region, and/or graduate students associated with that section

DEPARTMENT OF FISHERIES & OCEANS
CENTRAL & ARCTIC REGION

PUBLICATIONS ON ARCTIC CHARR CULTURE
BY THE AQUACULTURE RESEARCH SECTION
AND/OR GRADUATE STUDENTS ASSOCIATED WITH THAT SECTION

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APPENDIX 2

Reprint of "Arctic charr culture Bulletin, No. 1, June, 1990, Department of Fisheries and Oceans, Central & Arctic Region.

ARCTIC CHARR CULTURE BULLETIN

NUMBER ONE □ JUNE 1990

Research on Arctic charr culture technology continues both at the Rockwood Aquaculture Research Centre (previously called the Rockwood Experimental Fish Hatchery), Gunton, Manitoba and the Freshwater Institute Science Laboratory, Department of Fisheries & Oceans, Central and Arctic Region, Winnipeg, Manitoba. Each year researchers learn more about Arctic charr and some of the differences between raising Arctic charr and other salmonids. Many clients in the aquaculture industry have been raising Arctic charr from 1 to 3 or 4 years and have requested information on broodstock. The following relates some information about Arctic charr broodstock which may be helpful. Other Arctic Charr Culture Bulletins will be written if we recognize a need for information in a specific area and/or as more information from our research becomes available.

STOCK DIFFERENCES

J. Tabachek and B. de March

SPAWNING PERIOD:

The stocks of Arctic charr at the Rockwood Aquaculture Research Centre come from 3 locations and each stock spawns over a different period of time:

Nauyuk Lake, N.W.T.	68° 15'N	August 21 to mid September
Norway	61° 37'N	September 21 to October 31
Labrador	56° 39'N	October 1 to early January

The Nauyuk Lake and Norwegian stocks spawn over a much shorter time period (4-6 weeks) than the Labrador stock (3 months). Most producers received eggs from the Labrador stock since it is the only certified stock of Arctic charr which is available for transfer. Temperature and photoperiod can influence the spawning period. At the Rockwood Aquaculture Research Centre, a natural Winnipeg photoperiod and low water temperatures of 7-9°C are used. For comparison, Winnipeg is at a latitude of 49° 54'N. In 1989 the spawning of all the stocks was about one month later than usual and we have no explanation for this.

Fisheries and Oceans / Pêches et Océans

Canada

FECUNDITY AND EGG SURVIVAL:

For the certified Labrador (Fraser River) stock which were received as eggs in the fall of 1984, the first spawning occurred in 1987. This is the stock that has been shipped to producers across Canada.

Year	Female weight (kg)	No. of eggs		% Eyed		% Hatch		% Hatch of those eyed	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
1987	0.5-1	1950	-	50	-	28	-	63	-
1988	1-2.5	3300	1500-7500	72	0-99	60	0-96	83	6-100
1989	2-3	3900	1650-8000	35	0-97	-		-	

The reason for the decline in % eyed eggs in 1989 is still under investigation.

The Nauyuk Lake stock of Arctic charr produces fewer eggs than the Labrador stock. While the Labrador stock produces 3000-4000 or more eggs, the Nauyuk Lake stock generally produces 1200-2200 eggs. This is typical of what happens in the wild with both stocks. The Norwegian stock produces about 3000 eggs. Under hatchery conditions, the Labrador and Norwegian charr start to spawn at 3 years of age, the Nauyuk Lake stock do not start to spawn until at least 4 years of age and most first spawn at 5-6 years of age.

OTHER DIFFERENCES:

In physical appearance, the most conspicuous differences between the three stocks of Arctic charr at the Rockwood Aquaculture Research Centre are between the Norwegian and the Canadian (Nauyuk Lake and Labrador) stocks. The Norwegian stock has more black pigmentation and a more muscular appearance. There is greater variation in the growth rate of the Norwegian stock although this may not increase with time as much as in the Canadian stocks.

The Norwegian stock grows more slowly and is smaller at maturity than the Nauyuk Lake or Labrador stocks. The Norwegian stock never reaches the larger adult sizes that the Canadian stocks do. "Hybrid vigour" does not seem to occur when the Nauyuk Lake charr are crossed with the Norwegian charr. The offspring seem to be intermediate in size and colouration and the hybrid populations may in fact have more size variation than the pure strains.

The Norwegian stock produces smaller eggs and thus smaller fry than the Canadian stocks. Although the hatchability of the Norwegian stock has been higher than that of the Canadian stock, there is higher mortality at first-feeding with the Norwegian stock. This can be reduced by increasing the water temperature to 10°C at first-feeding.

PHOTOPERIOD

B. de March

Wild Arctic charr populations experience strong seasonal changes which are important in the timing of events such as maturation and spawning. There are many reasons to believe that this is important to the health and management of broodstock. Unfortunately, a "formula" approach that ensures synchronized maturation has not been developed yet.

Presently, most hatchery broodstock are maintained at a Winnipeg photoperiod, which reaches a maximum of 16 hours light in June and a minimum of 8 hours light in December. After approximately 8 years, all stocks still spawn in the fall. We also know that fish kept under artificial summer conditions all winter will not spawn well the next fall. With the Winnipeg photoperiod, the stock from the coldest northerly location, Nauyuk Lake (68°N), spawns earliest and the Norwegian stock, from the same latitude but a warmer climate, spawns later. Both of these stocks experience 24 hours light and 24 hours dark for several weeks each year in their natural habitat. The stock from Labrador, Canada (57°N), which experiences a maximum of 19 hours light and many hours of dawn and dusk in its natural habitat, spawns the latest. It appears that the fish from the most severe climates respond most strongly to the changes in our hatchery. We will attempt to manipulate spawning this year by using this knowledge.

One approach that has worked at the Rockwood Aquaculture Research Centre is as follows:
1) Maintain fish on a Winnipeg photoperiod until their demand for food decreases, which will probably be at spawning (late fall to December).
2) Maintain this low daylength and/or impose colder temperatures (6°C in our case) for several months.
3) When fish start to feed actively again (in our case, mid-April), return to the normal Winnipeg photoperiod and growth-promoting temperatures.

We still do not know whether the cues that reset the "biological clocks" for the development of eggs and/or spawning are short or long daylength, or cold or warm temperatures. At this point, imitating a natural year, even if in segments may be the best approach.

SELECTION AND CULLING OF BROODSTOCK

B. de March

When maintaining broodstock, producers and researchers are faced with the somewhat opposing objectives of selecting for and maintaining the largest and healthiest fish, and at the same time, maintaining some genetic diversity. If we simply select the largest fish from a tank, we may discover that they all are siblings and inbreeding problems may arise in later years. If we "mass fertilize" eggs, that is, mix all eggs and milt in one container, we may discover that one male is responsible for all the fertilized eggs, and the same inbreeding problems may arise in the future.

For non-experimental work, staff at the Rockwood Aquaculture Research Centre now do only one-to-one crosses (or at most two-to-one) when working with broodstock. That is, each female is crossed with one male (maximum two males) and many such crosses are made. This gives all individuals in the population an equal chance to contribute to the gene pool. These individual crosses or families are incubated separately. You can put plexiglass dividers in a Heath tray to keep each family separate. At some point after eyeing, the same volume or number of eyed eggs are taken from each family and pooled to form the future brood stock. An alternate but less ideal way would be to incubate an equal number of eggs from each cross right from the start in an undivided Heath tray.

There are several problems associated with culling fish. If fish are culled sometime after the onset of maturation, but the sex of the fish is not yet evident (for example 2-year olds), we may discover that most of the selected animals are of the same sex. When culling two-year olds, I have taken the following approach: 1) I decide how many animals I want to keep, 2) I pick one half of these from the largest fish in the tank, 3) I pick the other half as the most colourful fish in the tank. I seem to have maintained a fairly good sex ratio, biased slightly towards more females by using this approach.

ALTERNATE YEAR SPAWNERS

J. Tabachek and B. de March

We have evidence now that some females may be alternate year spawners. That is, some females do not produce eggs every year. We do not have enough information yet to determine if this occurs in all stocks or what proportion of the female population is expected to be alternate year spawners. This can also occur in the wild so we should not be surprised if all the females do not produce eggs every year. At this point, all we can do is advise you that this may occur. We recommend that you do as we have done and tag your fish so that you can follow the progress of each fish individually.

In the years that females do not spawn they can be very skinny. If these are culled as "inferior" fish, next year's broodstock may be destroyed. Until we can define conditions that ensure that females spawn every year or can select for those individuals that spawn every year, it is probably a good idea to cull very conservatively after animals have reached sexual maturity.

FREQUENCY OF SPAWNING CHECKS

J. Tabachek

Once the female ovulates, the eggs can be stripped and fertilized. Research with the Nauyuk Lake stock of Arctic charr indicated that the eggs over-ripen very quickly once ovulation has occurred (Krieger et al. 1988. Bull. Aquacult. Assoc. Can. 88-4:34-36). If eggs were stripped and fertilized within 4-7 days after ovulation, there was only a minor reduction in % eyed or hatched. However, if 11-14 days passed before the eggs were stripped, then the % eyed and % hatched declined markedly. Therefore, it is recommended that Arctic charr broodstock be examined at least every 7 days. Rainbow trout eggs over-ripen less quickly and it has been recommended that rainbow trout broodstock be examined at least every 10-14 days to achieve optimal survival.

SPAWNING TECHNIQUES

R. Olson

ESTABLISHING THE SEX OF A FISH:

Establishing the sex of Arctic charr by visual inspection is virtually impossible until the fish reach three years of age. At age three, as first spawning approaches, some differences between males and females may be observed:

- bodies of the males may become more slender those of the females. Even before egg development, females becomes obvious.
- colouration of the males may be brighter than that of the females, especially the under-bellies, which may become yellow or orange in colour. Note: if pigmented feeds are used, charr will be red-orange.
- snouts of males may become more pointed and many will begin to develop a kype.
- snouts of the males may also become a lighter brownish color when viewed from above, unlike the females.

Most of these characteristics will become more obvious as the spawning time approaches and less obvious after spawning is complete. Therefore, at spawning time, it would be wise to tag the fish, using one colour tag for males and another for females.

We have been fooled by charr - especially in believing that some fish were females. We have had some Labrador charr (especially large silvery ones) with absolutely no physical signs of being male until they were 5 years old. Then, they developed a kype and male colouration and produced milt for the first time at 5 years of age - 1-2 years later than others in the population.

FEEDING DURING THE SPAWNING PERIOD:

Past spawning records of the stock will indicate the approximate time when spawning can be expected to start. A decline in feeding activity is also a good indication that the fish are approaching spawning time. We usually begin to check our brood stock at 10 day intervals at least 3-4 weeks before this date. When some females appear to be very well developed, and are estimated to be very close to spawning (1 week), we stop all feeding to that group of fish. This allows adequate time for the fish to be "cleaned out". If feces are expelled into the spawning pan during spawning, fertilization will be reduced drastically. If tank space is available to hold spawned out fish, these can be held separately and fed lightly. After one month, if some fish have not spawned, they can be fed lightly the day after their weekly spawning check.

SPAWNING METHOD:

Ripe females should be sorted out in advance along with enough males to use with them. The ratio of females to males will depend on the planned use of the offspring:

- if mass egg production is required to produce market fish, then as many as 4 or 5 females could be spawned at one time into the spawning pan (provided no water is allowed to enter the pan during spawning). The eggs in each pan could be fertilized with 3 or 4 males.
- if egg production is required to produce future brood stock, then one female should be spawned at a time and fertilized with 1 or 2 males (as described in "Selection of Brood Stock") and egg groups held separately.

Materials required: - wool mitts to wear when handling the fish, spawning pan, dry cloths, small container for milt, feather, container of fresh water for fertilization, lots of fresh water for rinsing.

Procedure:

- Anesthetize fish to be spawned (we use phenoxyethanol 0.25 ml/litre water) until they can be handled without movement - anaesthetize only enough fish at one time to do one pan of eggs.
- Dry spawning pan with cloth before spawning.
- Dry underside and tails of all fish immediately before spawning. Any water contacting the eggs before fertilization will cause the micropyle of the egg to close prematurely and prevent fertilization.
- Spawn eggs from female(s) into pan ensuring that no water enters the pan.

- Spawn the milt from a male into pan. If more than one male is being used, combine the milt from the males in a separate container (with absolutely no water in the container) before adding it to the pan of eggs.
- Use a feather to stir the milt into the eggs and distribute it evenly throughout the eggs.
- Add only enough fresh water to completely cover the eggs (more water will only dilute the milt). Stir slowly and gently for one minute, then every 15-30 seconds after that for another minute.
- At this time all fertilization should be complete. Eggs in the pan should be rinsed with fresh water until they are clean. Timing here is very important. Approximately 10-15 minutes after fertilization, the eggs will begin to water harden. During hardening they will be extremely delicate. We try to put the eggs in an incubator or some temporary container within 10 minutes (maximum 15 minutes) where they will not be disturbed for two hours. After 2 hours, they are no longer delicate and for approximately 48 hours they can be moved (or shipped) to the location where they will be incubated. After 48 hours they become very delicate again and should not be disturbed for any reason until they are eyed. During this time, regular formalin treatments may be used to prevent the growth of fungus.

Other fish culturists will probably have variations to this method. However, this method works well at the Rockwood Aquaculture Research Centre and we believe if both the eggs and milt are good, very high survival rates are possible.

IMPORTANCE OF REMOVING OLD EGGS

J. Tabachek

If eggs are not removed from the female, then the contents of the eggs will gradually be resorbed but the shells will remain. We have found that if old eggs are not removed from the female charr, the old shells will form a "plug". The following year, this plug will make it very difficult to allow eggs to be released. You will find that the female will be ripe and bulging with eggs but you will not be able to release them. Sometimes, you will examine a female for a period of several weeks and try to release these eggs. When you finally dislodge the plug of old shells and the eggs are finally released, they will be over-ripe and will have very low chance of being fertilized. Therefore, it is very important to examine all the fish and remove all the old eggs. You may find that a small proportion of the females may produce eggs at 3 years and it is important to remove these eggs. In addition, since 10% of the eggs will probably remain in the female after spawning, all females should be examined at least once or twice after spawning to remove the remaining eggs.

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Carol Kemp designed the front page of this bulletin.

A French translation of this Newsletter can be received by sending a request to J. Tabachek at the following address.

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Issued by:

Department of Fisheries and Oceans
Central and Arctic Region
501 University Crescent
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APPENDIX 3

Generic Draft Copy of "Joint Department of Fisheries and Oceans - Private Sector Technology Transfer Project: Terms of Reference"

Generic Draft Copy
June 15, 1990

JOINT DEPARTMENT OF FISHERIES & OCEANS - PRIVATE SECTOR

TECHNOLOGY TRANSFER PROJECT

TERMS OF REFERENCE

1. PARTIES TO THE AGREEMENT

a. Department of Fisheries and Oceans (referred to herein as DFO)

DFO Central and Arctic Region
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6
Canada

b. Client ... (referred to herein as The Client)

2. TITLE OF PROJECT

3. DESCRIPTION OF PROJECT

a. Objective:
This section should contain the following information about the client:
- type of facility
- objective if the client in the production of Arctic charr ie. production of eggs, fingerlings or market-sized fish
- recognized support from governments or other agencies
- type of technology that the client is requesting from DFO in terms of information, advice, eggs or fish, etc.

As a component of its mandate, DFO has a responsibility to transfer technology and communicate information to the private sector. Joint DFO-private sector projects such as this one will constitute a way of transferring technology developed by DFO and information gathered from DFO research to the private sector. DFO will publish as a Technical Report a review of the data generated by this project. The purpose of this agreement is to delineate DFO's responsibilities as they relate to this particular project.

b. Methodology:

This section should contain information on:
- the number of the client's staff with whom DFO would be interacting
- how DFO would transfer technical information and advice to the client's staff

To transfer Arctic charr technology developed at the Rockwood Experimental Fish Hatchery to the client, DFO will provide the client's staff with the technical information and knowledge that they require to raise Arctic charr. If required, DFO will provide these employees with training in Arctic charr husbandry techniques by having the clients' staff work at the Rockwood Experimental Fish Hatchery with members of the hatchery staff. Any and all costs associated with such training is the responsibility of the client.

The client will collect the growth, survival and feed data required to monitor and assess the performance of Arctic charr from the eyed stage to broodstock. These data will be collected at 3-month intervals (or more often if possible) during the first year of fish growth and at 4-6 month intervals thereafter. The data will be submitted on the appropriate forms (sample attached). These data will provide the basis of a Technical Report to be written by DFO with the assistance of the client.

DFO will provide the project with certified Arctic charr eggs from Rockwood Experimental Fish Hatchery. The number of certified eggs provided will be dependent on the production success at Rockwood Experimental Fish Hatchery. During the first year of the agreement, every effort will be made to supply 10,000 eggs. If sufficient eggs are available, the client will be provided with a maximum of 30,000 eggs per year of the agreement or per year of its renewal. DFO does not charge for materials provided under Technology Transfer. However, DFO does require clients participating in the programme to help support it by contributing to the materials for the programme. To ensure that each client's contribution is equitable, DFO has assessed programme requirements on a cost per eyed egg basis. The cost to the client will not exceed $0.04 per eyed egg. Costs for any other sizes will be negotiated. The client will provide DFO with some commodity such as fish feed directly used in the programme.

4. PERIOD

The period of the agreement shall be until March 31, 19__. The agreement shall be renewable annually for two additional years from the spawning season at which the client first received 10,000. The renewal process shall be initiated upon the request of the client. Both parties must agree to the renewal for it to be approved.

5. TERMS AND CONDITIONS

a. It is understood and agreed that results of the pilot study will be published cooperatively by DFO and the client as a Technical Report. The client may identify economical or financial data that he/she does not want published. The client is responsible for submitting data every 4 months on survival of eggs and survival and growth of fish. The data is to be submitted on the appropriate forms (sample attached).

b. The client is solely responsible for any and all construction costs. DFO will provide only technical advice and information.

c. The client is solely responsible for any and all costs for the shipping of fish and fish eggs.

d. Eggs provided by DFO for the client are not for resale.

e. The client is responsible for the construction engineering of the project and assuring the project meets building and safety codes.

f. The agreement is not to be construed as an assignment of any rights that DFO may have to copyrights, trademarks or patents. It is further understood and agreed that if any patentable developments result from this project, the ownership of the patent(s) shall be the subject of later negotiations between the two parties of this agreement and subject to patent ownership as may be dictated by government patent regulations.

g. The client will exhibit at the site of the Pilot Project a sign indicating the participation of DFO, Central and Arctic Region in this Technology Transfer project, for the duration of the Agreement and any renewal period of the Agreement. The sign will be provided by DFO.

h. The Agreement may be terminated by either party, after demonstration of cause, and giving six months notice in writing to the other party.

i. It is understood and agreed that this agreement is a contract for the performance of services and that DFO is engaged as an independent contractor; neither DFO nor any officer, servant, or agent of DFO shall be deemed to be an employee, servant or agent of the client.

Signed on behalf of DFO by Mr. P. Sutherland and on behalf of the client by the signing officers duly authorized on their respective behalf this

_____ day of _____ 19__.

_____
Witness

_____
P. Sutherland
Director General
DFO Central and Arctic Region

_____
Witness

_____
Name of Person Signing
Position
Name of Client

APPENDIX 4

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